FIG. 21.—THE GREATEST OF SPIRAL NEBULAE

The great nebula in Andromeda is of immense dimensions and probably very distant. It has been thought to be in really a stellar system outside our own

SOME CHEMICAL PROBLEMS OF TODAY

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I

THE PRIZES OF CHEMISTRY

THERE is nothing in the action of the present-day forces of Innovation that bears any of the symptoms of past history. For the first time in any known era these aspirational forces have gained control, not through the explosive violence of revolution, but through the processes of evolution. As a result we find ourselves saved from revolution, living in an age intensely dynamic, ignorant of where we are going, but on the way.

As is the case, however, with all evolutionary processes, the new and the old exist in curious and incongruous juxtaposition. This state of affairs is particularly impressive as it refers to the evolution of industrial processes and methods—an evolution which, while it is not proceeding in the open, as with governmental and social conditions, is nevertheless of immense significance to the immediate future.

For example, there came into my office yesterday two letters—one from an industrialist, saying, "One great trouble in business is that men are overtrained in the art of money-making through fraud, manipulation, and practically stealing it by indirection"; and the other from an inventor *re* the inventor, saying that "the possession of inspirational power is the cause of his financial downfall." These two men, one the user of invention, and the other the inventor, alike express a large agreement in the idea that one generally robs the other—that it is done by "indirection" is not particularly consoling. That they express a fact of past conditions is undeniable to any one who has ever tried to dispose of a new industrial process, but that they express a fact of general contemporary practice would be scandalously untrue. One of the most remarkable features of this swift industrial transformation that is proceeding is the continual replacement of the common type of commercial pirate, who in the past had directional power over the industries, by men technically trained in the knowledge of the schools and possessed of the determination that their specific type of industry shall win supremacy on its merits and not through the devious paths of business "indirection." To such men the inventor, the innovator, the man with a new idea, is welcome to a degree that is precisely graduated to what, on the basis of shrewd, careful scientific scrutiny, his idea is probably worth.

To-day, in fact, large fortunes are being accumulated by men of creative genius through the co-operation of corporations anxious, and more than anxious, to conduct their operations through the principles of progressive scientific practice. In order to illustrate the opportunities that are ready to hand for young men of scientific training and creative power, and as well to illustrate the anxiety of these large corporations to eliminate waste and to utilize new ideas, it may be interesting to the reader to place before him a few of the announceable inquiries that in the last five weeks have come before the writer merely in his positional capacity.

To begin: Away up in the silver-mining region of northern Ontario there exist vast deposits, tons upon tons—small hills, in fact—of waste silver-extracted residues from the mines. These residues are rich in *cobalt.* Cobalt is a silver-white metal with a faint suggestion of pink; it is tenacious, it can be readily polished, and it exhibits a high luster. It may be considered as a sister to nickel and a cousin to iron; like iron, for example, it is magnetic. *In the metallic state cobalt has found no application whatever in the arts.* Now, it should be remembered that it is not iron and that it is not nickel, but that as an elemental substance it possesses properties that differentiate it from every other substance on earth. Having unique properties, it ought to possess unique utilities, and common experience tells us that these unique utilities have only to be sought to be

found. As a mere hint of its possibilities, the writer was shown the other day a knife the blade of which consisted not of iron, but of pure cobalt with a trace of chromium.

Of course the future of this metal lies not in imitating iron or steel, but in transcending these for special purposes and in the utilization of its extraordinary wealth of compounds. Altogether, wealth, reputation, and service await the trained *chemiker* who has the intelligence and persistence to dig them out of these refuse deposits of northern Ontario.

As with cobalt, so with *tellurium*, a sister, or, it may be, half-sister, to sulphur and selenium. For years tellurium residues from certain mining processes have been hawked about university laboratories, looking for this same intelligence and persistence—and so far in vain. One of the very few tellurium utilities with which the writer is acquainted takes advantage of the exceedingly mephitic odor of one of its compounds. It seems that certain society physicians, through this substance, in the form of pills, are able to convey to the breath of patients upon whom it is desired to enforce rest and seclusion a social impossibility—a truly dignified rôle for one of the eighty-odd elemental components of our universe! Out in Colorado, as a by-product of one of the electrolytic industries, many tons of beautiful, pure metallic tellurium lie piled as briquettes in beautiful inutility—elemental tellurium, absolutely unique in itself and throughout the full range of its compounds.

Still another element begging utility is *silicon*. In combination, it constitutes more than one-quarter of the crust of the earth; in its elemental condition it is produced at Niagara Falls to the bare extent of about four tons a day, useful for its deoxidizing power in steel manufacture, for the purpose of introducing electrical resistance in electrical circuits (for its resistance is somewhat higher than that of carbon), and, potentially, I should say, for coating in the form of silicide the surface of large steel containers, or possibly even of acting as the actual substance of such containers. Were its utilities fully realized, it would doubtless be produced at the rate of four hundred tons a day.

Writing of pure elemental substances—there is chemically pure iron now produced by an electrolytic process. A pure metal is vastly different from a metal almost pure, and this pure iron (absolutely C. P. but for a trace of hydrogen) is certainly a novelty. The minutest traces of certain impurities may have, either for good or for bad, an astonishing effect. Having, therefore, a metal like iron, fundamentally pure, it may be expected that the addition of metals equally pure will lead to new alloys with new properties. At any rate, it thus begs utilization for unique industrial purposes.

Silver, again, is a metal that has its problems. The tarnishability of silver, particularly to people who live in the smoke-enveloped cities of the present day, is a time and muscle consuming annoyance. It is not sur-

prising, then, that a prominent company manufacturing silverware should inquire as to the possibility of adding small quantities of other elements to silver, with the idea of lessening or eliminating its tendency to tarnish. So far as the writer is aware, no work of any kind whatever has been carried on with such an idea in view, and it thus certainly offers opportunities of distinct promise.

Possibly, of all the anxious inquiries coming in to this department, those pertaining to enamel are the most notable. It is extraordinary, the diversity of demands made by manufacturers for a really resistive enamel with which to coat their wares, and equally extraordinary is the entire inability of manufacturers of enamels to respond to their demands. One manufacturer desires an enamel for coating the maleable iron shells used on the Bunsen burners employed in the incandescent gas-lighting mechanisms. The enamel used is destroyed by oxidation and by the ammonia and sulphur found in the gas. Another manufacturer desires an enamel resistive to the reagents used in photography; he manufactures photographic machinery and photographic trays. Still another is desperately in need of a resistive enamel with which to coat his storage-battery cells. The art of enameling cooking utensils is practised under medieval conditions of superstition and empiricism, and in no instance do these cooking utensils even remotely approximate the ideal. No enamel in the market intended

for the lining of iron or steel containing vessels responds to the needs of manufacturers.

Another subject of inquiry almost equal in importance to that of enamels is that of bleaching agents. We have had to answer many and grievous letters of inquiry from manufacturers desirous of using bleaching agents which do not destroy the fabrics which they bleach. Here is one who manufactures annually some thirty million yards of antiseptic gauze, and here is another who desires to color unfinished yarn without bleaching. The plaint in each case is that bleaching destroys from twenty five to thirty per cent. of the strength. One anxious inquirer makes horn buttons, and he finds, to his chagrin, that while he can perfectly bleach his buttons, after passing through the laundry *they revert to their original color*. In these and all other bleaching processes it may be said that there is no bleaching agent of an oxidizing character that does not injure the fabric upon which it is employed. Possibly sodium perborate is less injurious than any other.

Still another matter of much contemporary inquiry and anxiety relates to the increasing scarcity of wood—particularly the hard woods. Many men are to-day making and selling composition woods made out of wood-waste—for the most part sawdust. This sawdust is mixed with a binding material, and as such is finding its way into the market as flooring compositions. Still other men manufacture their composition wood out of

waste wood-pulp from the paper factories. Both types of manufacture have the regular tribulations of an unperfected process. Composition wood has an unquestionable future, but its success depends upon the discovery and utilization of a suitable binding material, and this I am sure has been found either in *bakelite*, that remarkably strong and resistive material discovered by Baekeland, or by *redmanite*, a different substance which is being developed in our laboratories at the University of Kansas. Apart from artificial wood, a great desideratum is artificial wood for special purposes. Thus, owing to the serious depletion of the cork-trees, an artificial cork is desired.

The art of paper-making, into which fifty per cent. of material of pine and hemlock passes, is, according to certain inquiries, by no means in a satisfactory condition. Owing to tariff conditions, actual and potential, and for other reasons, it is necessary now to make paper with qualities different from those that obtained in the past. Thus, a paper is now desired having a higher finish on a lighter weight and for a less cost; this is as yet an unsolved problem. Did the paper-makers but know it, the solution of the problems of paper manufacture and the provision of cheaper paper for all of us that print or read lies in the transformation of the nitrogenous waste material and residues from the pulp mills into valuable and utilizable chemical substances. It is incredible that in this age of progress fifty per cent.

of the wood should pass heedlessly down the drains. Composition woods and imitation woods are hardly more desired than substitute woods. There is a certain company that uses immense quantities of maple; now, owing to the increased scarcity of maple, its cost has become prohibitive to that branch of manufacture. This company is persuaded that the common gum-tree of the Southern States, when properly treated, would yield a wood capable of substitution for maple, and it would express itself as under infinite obligations to any one who would demonstrate this free of cost.

The wood refuse from the sawmills, cornstalks, waste paper—indeed, all kinds of cellulose refuse are industrially convertible into denatured alcohol, and consequently many inquiries arrive as to the industrial value of such materials. For example, one gentleman in California has immense deposits of the sawdust of fir and of yellow and sugar pine, and all of it beside the way station of a railroad; naturally, he desires "to know a thing or two." The only hamperment to the conversion of wood refuse into denatured alcohol is the fact that the process is at present in the hands of one corporation and its ramifying connections; if the holders of wood refuse will but "bide a wee" until such time when, through the exhaustion of an adequate gasoline supply, industrial alcohol becomes inevitable as the source of power for automobiles and other power-con-

suming mechanisms, they will find their material both useful and valuable.

Finally, in relation to this business of wood supply, there are fiber-making plants whose possibilities are hardly more than suspected. Down in New Mexico there is an immensely plentiful and widespread form of vegetation known as the yucca plant, or, vulgarly, as the "soap-weed" or "bear-grass." This grass yields a fiber of remarkable tensile strength and quality. The only reason that the fiber-making possibilities of the grass have not been exploited is because it has not been properly investigated by men of scientific education and training. Consequently, when there is needed a suitable solvent for the gummy matter between the fibers or an efficient bleaching agent for the fibers themselves, the people interested in "bear-grass" are as helpless as babes.

Farther south, in Old Mexico, there are people worriedly concerned with one of the rubber-trees of that region, the *Castilloa elastica*, as to the best method of tapping these trees and the subsequent management of the milk. In New York they are also worried about rubber, for they desire to print rubber sheets "as per sample, after the cloth has been finished"; it seems that the present printing of rubber rubs off.

One of the most interesting problems as related to fruits concerns the utilization of cull oranges and lemons. "Culls" are oranges or lemons that are deformed or

overripe or underripe or that are slightly bruised. Out of the 30,000 cars of oranges shipped last year from California, the contents of at least 600 cars were thrown away. In Florida they cull at least 50,000 boxes a year, but the growers would gladly cull 250,000 boxes if they had but a profitable use for them. We have recently been highly honored by the Florida Citrus Exchange in placing with us, at the University of Pittsburgh, this problem for solution. We hope to succeed by preserving the juice of these waste oranges in such a way that it does not conflict in the slightest degree with the pure-food laws. We hope also to extract and utilize the oil which the rinds contain, the bitter principles underneath the rinds, and the citric-acid constituent of the juice itself.

But if the Western coast is interested in oranges, it is also interested in oysters. In far-away Seattle the oystermen are deeply concerned to utilize science to the furtherance of their business. The Western oyster is a curious little undersized creature, markedly different in its nature and in its ways from the oyster of the Eastern coast; for one thing, it is hermaphrodite. So different, indeed, are the two types of oyster that no knowledge gained of the Atlantic oyster is applicable to that of the Pacific. The Western growers desire not only to increase the output of the oyster natural to that habitat, but as well to transplant the Eastern oyster to the Western coast.

One of the most remarkable inquiries from the Far West relates to a new use for a species of kelp or seaweed, abundant on the Western coast. Certain individuals have succeeded, through long experimenting, in emptying its cells and in extracting from the cell-walls its nauseating taste, in such a fashion that they have been able to refill the cell cavities with food products and to make of the otherwise worthless sea-kelp a valuable food; they desire a market for their products, which are kelp candies, jams, and pickles.

Another set of queries, wholly different from those that we have so far considered, concerns uses for raw materials. Despite the extent to which the raw materials of manufacture have been exploited and segregated in ownership, there still remain deposits valuable but not understood by the owners. Men wish to know what to do with large deposits of oil shale near Vermillion, Ohio. Some of this rock, a short time ago, caught fire and burned continuously for eight weeks. A lady in California possesses three hundred and fifty acres of diatomaceous earth, valuable for polishing metals, as mineral wool in cold-storage plants, in place of asbestos for steam-pipe coverings, as the "dope" for the absorption of nitroglycerin in dynamite, in the manufacture of fireproof brick, and for many other purposes; she wishes to know what she can do with it. Over in Utah there exist immense deposits of asphaltic substances whose uses, already manifold for varnishes, soaps, and binding

material, will be infinitely extended. To such an extent is this impressed upon certain men that they have established with us at the University of Kansas a research for this specific object.

Problems of manufacture in the traditional industries swarm in upon us—problems that a few years ago were not only not worried over, but were not known.

Is it possible to recolor and refinish leather? Certainly it is. In the process of chrome tanning, the flanks and shoulders of hides are flat, very, very flat, in the mineral tannage employed. The best answer I can give to such a question is that were I a young chemist seeking an *arbeit*, I should plunge into leather for a life's work. What science does not know about leather would fill volumes.

Shoe-blacking? How to color it, how to treat waxes to produce certain results, and how to arrive at certain results by combining waxes. Is it possible to improve the art?

Ink also has its troubles. A man wishes to dissolve Ghatti gum and at the same time preserve its adhesive properties. A lady writes from a town where the water is hard, suggesting that we should discover a hard-water soap—*i.e.*, a soap the curds of which in hard water would not stick to the sides of the bath-tub, as she says, "closer than a brother!" It merely means the discovery of a soap whose calcium and magnesium salts

are soluble—a legitimate object of research with not improbably a successful ending.

Then there is glue; a certain manufacturer desires a water-proof glue for holding down the strips of artificial flooring to the floor. But this is a mere incident; as a matter of fact, if there is one substance of which we are densely ignorant, chemically, physically, and biologically, it is glue, and it is therefore a real pleasure to announce the establishment at the University of Pittsburgh of a fellowship for an investigation into the very fundamentals of glue, which, by the way, involve all colloidal chemistry, a new-born branch of chemistry that hardly anybody knows anything about.

Passing rapidly over announceable problems as they appear—the dentists are desperately in need of a cement that is "absolutely" insoluble in the mouth; manufacturers of toilet preparations need a method of compressing powdered pumice, for "mixing it with Portland cement is not satisfactory." The glass-makers are eagerly desirous of a method of manufacturing a ruby glass in the pots, for, as it is and always has been, the ruby color of the glass flashes out only on one or more reheatings—an expensive operation. A certain enormous manufactory of artificial cereals in packages is seriously concerned with the damage to these same packages by rats, and it desires, if possible, some method of making these packages distasteful to rats without conflicting with the pure-food laws. Another, equally huge in the

extent of its manufacture and its operations, is embarrassed through the curious fact that while grasshoppers will have nothing to do with binder-twine made of imported flax, they avidly devour the domestic product, and with a consequent loss of a million a year to the company concerned, to say nothing of its loss of reputation among the farmers. Manufacturers of pharmaceutical preparations long ago found that they could preserve the widely used hydrogen peroxide by the addition of small quantities of acetanilide, etc., but now, under the slogan, "Let the label tell," they are embarrassed, never imagining that in all likelihood the decomposition of hydrogen peroxide is due to the catalytic influence of the small quantities of alkali in the glass of the containing vessels.

On the northern coast of western America the shipping interests need an efficient anti-fouling and anti-corrosive paint for the hulls of iron vessels; they are at present paying $2.60 for one and $1.35 for the other, and the merits of both are "alleged." Science has still to discover a paint that, once on the hull of an iron vessel, will actually and truly prevent fouling and corrosion. Very interesting is the desire of one company to utilize its vast deposits of fluor-spar in the manufacture of hydrofluoric acid, the only objection to the widespread use of hydrofluoric acid being the melancholy fact that it attacks glass. On the basis of contemporary knowledge, however, it is easy to indicate

methods of coating glass that would make it a safe containing vessel for hydrofluoric acid.

More numerous than any others are inquiries concerning varnish; literally, everybody everywhere demands better varnish. The blades of safety razors are a subject of some inquiry. The remarkably high price of a certain type of these blades suggests that the manufacturers thereof might readily afford an investigation into the steel out of which they are made, particularly with a view to making them a little less rustable. Why cannot the manufacturers of lubricating oils sell their product without admixture with animal fats, which, in certain types of engines, are exceedingly objectionable? They *will* mix in these fats to such an extent that it is almost impossible to obtain lubricating oils free from them. There is no thermo-couple used in industrial operations that is a satisfactory measurer of high temperatures; it is not surprising, then, that queries arrive as to the possibilities of research for the production of high-temperature thermometers.

The great business of transporting bananas, cocoanuts, and so on, from the West Indies leads to the question as to what these transporting companies do with their immense quantities of banana trash, as well as to what use they put the husks of cocoanuts. The question is easily answered; they do nothing; and yet this banana trash is a valuable product, and the husks of cocoanuts have at least paper-making possibilities. The

people of America have been so busy buying essential oils and perfumes from Europe that they have not as yet realized that many plants indigenous to their own country possess oils of high value whose extraction would be profitable; at present these plants cover the fields and forests only to sink back into the soil. Let the reader who has naturally an interest in such a subject look up the price of oil of wintergreen, and then let him speculate as to why he should not plant the berries of the wintergreen under his own hardwood trees, and annually thereafter distil the oil from the resulting cut plants; nobody as yet has tried to do this. The present practice is the old practice—that of sending out people over the country-side who ruthlessly pull up the plants and extract the oil by means of portable stills—naturally an expensive and destructive process.

Among so many inquiries, it is inevitable that there should be some stamped with the hall-mark of the old-time "inventor." I am recommended, for example, to a certain mud as a sure cure for rattlesnake bite, and to the exploits of a certain ancient tramp of Iowa who is able to burn out cesspools with a pinch of powder. One earnest "inventor" has a method of removing the rind of potatoes, the loss of which in kitchen practice exceeds seventeen per cent.; another desires to make a shaving cream instead of soap; still another has "invented" a method of obviating the necessity of "licking" postage-stamps and envelopes; while a gentleman in the North

is "positive" that the study of arteriosclerosis would eliminate old age and death. Why do not these ingenious people realize that solid opportunities for wealth lie everywhere at hand? Consider the fact that it is only necessary to bore a small depression in a phonograph record at the end of the script to insure that the needle will stop the machine without the necessity of nervously waiting to "turn it off"; since the phonograph people do not know this, it should be "worth money" to their informant.

The many and important actual opportunities that lie everywhere at hand for applying scientific knowledge and the scientific method to the manufacturing needs of men make one frankly consider why trained and earnest men should devote laborious days to making diketotetrahydroquinazoline, or some equally academic substance, while on every side these men are needed for the accomplishment of real achievement in a world of manufacturing waste and ignorance.

The inquiries listed above are but a fraction of those that we might disclose. They are illustrative and significant of the transformation that is sweeping over American industry.

1911.

II

THE QUESTION OF THE ATOM

THE question of the atom is really one of the most interesting and informing in contemporary knowledge. It is so interesting because the mere question "*Is* there an atom?" has been the *casus belli* of a fratricidal strife which for almost a generation has divided chemist against chemist, and it is so informing because it illuminates so clearly the workings of human nature in those cold regions of Science in which presumably, and ideally, human feelings have no place. The question "Is there an atom?" has associated with it all the *odium theologicum* of medieval days, all the proverbial hatred of contending divines, and, when chemist meets chemist, because the attitude of each man is fixed, because it is a personal matter, it is as impossible to discuss in intellectual honesty as either politics or religion. This is, of course, sufficiently curious and wrong, but the wrongness of it is emphasized through the consideration that it is a fundamental matter in the teaching of chemistry. When about half the chemical departments of the colleges and universities are teaching chemistry on the basis of the atomic theory and the other half refuse to mention the

word atom, or mention it apologetically with a blush, and when, as is oftentimes the case, there is disaccord on the subject, and high debate, in any one instructional staff, it affords a poor prospect for a future crop of investigational chemists, and it may even be suspected that there is about the whole matter a certain unreason. All this may be matter of surprise to the cultured layman, who probably takes his atoms, as he does his microbes, as a fact. But atoms are not a fact, but a theory, and therein lies the root of the trouble. We have had many theories in the past, some of them great fruitful theories such as that of phlogiston, and of caloric, and of the corpuscular nature of light, and these theories are to-day nothing but discarded rungs in the ladder of man's advance. Is it not possible that the atomic theory is no more than these the expression of a truth of nature? Thus, one reason for all this regrettable disaccord is purely pedagogical, certain chemists believing that, owing to the tremendous utility and scope of the atomic theory in the explanation and elucidation of natural phenomena, some young gentlemen at the threshold of their science may find a quagmire of confusion between fact and theory, and therein a pitfall for their unwary feet. It is true that the physicist with his undulatory theory is not worried by such fanciful considerations, but cheerfully uses and teaches his light-waves, which, by the way, no man has seen any more than he has an atom. The biologist, too, is in no whit better case, yet he, too,

teaches and uses his theory of evolution without overmuch regard for the undiscriminating student. There must be other reasons for this curious attitude of certain informed chemists, though these can scarcely be considered in an article of this general character. Meanwhile it may occur to the reader that the refusal of certain chemists to base their teaching on the conception of atoms may be due to evidence against the validity of the atomic theory. No. On the contrary—and this will be the subject-matter of my paper. The fact of this disaccord is introduced here merely to apprise the reader that in presenting and drawing conclusions from some certain new and very interesting knowledge, this knowledge is subject to partisan interpretation, to such an extent that the layman who happens to peruse these pages may, perhaps, form a judgment concerning it as good as that of any average party to the controversy.

With regard to absolute knowledge as to the ultimate constitution of matter, we all recognize it as impossible. Science is like Palomides, "that good knight" of the Arthurian romance, who pursued a beast called Galtisant. It was a "questing beast" and forever uncatchable; nevertheless with Palomides it was his "quest," which, with quite human divagations and excursions, he religiously pursued. The ultimate nature of matter is the "questing beast" of science.

But about this matter, accepting it as phenomena, it is either infinitely divisible or it is not; there is no *via*

media. If it is not, then it is composed of ultimate particles. Now, the atomic theory states not that there are ultimate particles, but that there are ultimate particles of *chemical reaction.* It may be true, and, accepting the theory, doubtless is, that the ultimate particles of chemical reaction, or atoms, are themselves built up of particles smaller still. With these the atomic theory *per se* has nothing to do.

But about these ultimate particles of chemical reaction, or atoms, the evidence upon which the theory of their existence rests may be said to be all of chemistry, most of physics, and a large portion of every other field of natural knowledge; in other words, it is stupendous. This evidence, however, is wholly *inferential,* and so long as this is true there remains always the conceivability of some other explanation to account for the facts, innumerable though they be. But if we could take our atoms out of inferential into demonstrational evidence we should at once leap an infinity of difference in credibility—all the difference between the necessity of an indefinite piling of Ossa on Pelion of cumulative evidence, and a heaven of certainty where one fact is as good as a million. If we could but indubitably capture our atom! While I do not say that this can be done to-day the approach to its accomplishment is so close and the attack is, if I may be permitted to use the word, so "sporting," that it has an absorbing human interest.

This appears when one considers what it means in the way of difficulty, this capturing of an atom.

The spectroscope is one of the most delicate instruments for the detection of matter ever devised by man. With this instrument Strutt has been able to show that it is possible to detect the gas neon in one-twentieth of a cubic centimeter of ordinary air; and on the basis of Ramsay's work it is a fact that this quantity of neon corresponds to about one-half of one-millionth of a cubic centimeter. Transferring the statement to terms readily understood, there is a particular particle lost in a thimbleful of air with four million others: problem, find that particle. It can be done.

One would think that a particle so unimaginably small would approach fairly close to the dimensions of the theoretical atom, but such is not the case. This particle, on the basis of the current conception of the atomic theory, must contain about ten million million atoms. As Sir J. J. Thompson says in another connection, if we had no better means of detecting an individual man than an individual atom we should conclude that the earth was uninhabited. It is apparent that the spectroscope, delicate though it is, does not make a beginning in the attempt to capture the individual atom. So much for the difficulty.

Let us, however, disregarding the fact that an immense, incalculable number of facts of organic chemistry, other chemistry, mechanics, diffusion, expansion, spec-

troscopy, light, heat, electricity, magnetism, sound, meteorology, radioactivity, and so on and so on indefinitely, all lie beautifully arranged, correlated, and explained within their proper limits, and ever increasing in volume because of the atomic theory—disregarding all this, and despite the immense difficulty of it, let us ask ourselves either for demonstrational evidence or for inferential evidence with which the *Chemical* Atomic Theory, if I may so call it, has nothing to do.

There is one instrument which is as much more delicate in detecting the existence of small particles of matter as, under certain conditions, the spectroscope is than the human eye. This instrument, marvelously little known, is the ultra-microscope. With the best modern microscope the smallest particle which it is possible to see is about 1-7000th of a millimeter in diameter. This diameter is just about the length of half a wave of visible light. It is unreasonable to expect the best microscope to possess a resolving power greater than this, for with particles smaller than half the length of a wave of light they obviously cannot reflect the light by which they may be seen; for example, one cannot expect a grain of sand to reflect a water wave; the wave simply embraces the grain. Outside of the fact that the limits of visibility may be somewhat extended by using light-waves of short lengths, as with ultra-violet light and photography, there is one way by which success may be achieved. Particles, no matter how small, may

be seen if they are caused to emit a light of their own—to become sufficiently self-luminous. Whether this is a valid explanation of the observed phenomena, or whether the extension of visibility is due to illumination in a dark field, may be a matter of opinion, but the summarized facts are as follows. The light from a powerful arc-lamp or from the sun is passed through a strong condenser in such a fashion as to transform it into a superlatively intense but superlatively minute beam. This wisp of intense light passes through the windows of a cell and impinges there upon the substance under examination; the small area illuminated by it is then examined from above by a good microscope. As a result of this simple mechanism and under certain conditions there spring into visibility particles which are as small as the stars are distant. They are not unlike stars even in appearance as they lie twinkling there in the depths of the infinitely small. They are like stars, too, in that their actual shapes are not delineated, though they may be observed by the hour with fascinated interest. Even though it is actually true that their forms may not be observed, their average size may nevertheless be calculated, not in terms of theory, but of fact. Thus, in examining the particles of gold in ruby glass the area of the minute beam may be calculated, the number of particles of gold in this area may be counted, and since the weight of gold introduced into the glass and its specific gravity are both known, all the factors are pro-

vided for estimating their average size. So determined, the particles of gold in ruby glass average six-millionths of a millimeter in diameter. *The smallest particles estimable in a colloidal solution of gold measured* 1.7 *millionth of a millimeter.* This means that in its capacity for determining minute quantities of matter the ultra-microscope is thirty-seven trillion thirty-one billion times as powerful as the best modern spectroscope, which, as we have seen, is capable of detecting one-half of one-millionth of a cubic centimeter of gas. A graphic idea of the transcendent powers of this instrument may be obtained by examining the diagrammatic representations in Fig. 1. The little dots *f*, *g*, and *h* represent visible particles of colloidal gold some six to fifteen millionths of a millimeter in diameter and magnified ten thousand times to render them representable; the corresponding circle A represents a human blood corpuscle, itself an excessively minute object, magnified in the same degree.

Quite apart, therefore, from any inferential evidence, we have the positive demonstration of the fact that matter is capable of existing in the condition of discrete particles infinitesimally small. It therefore becomes an interesting matter to compare these particles of measured diameter with the calculated dimensions of our hypothetical atoms and molecules. This comparison is represented in Fig. 2. Here we have in figures *a*, *b*, and *c* the estimated diameters of the hypothetical molecules of

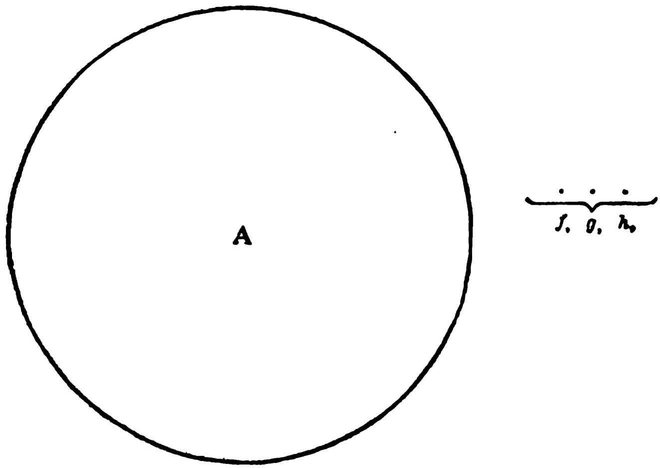


FIG. 1.—COMPARATIVE SIZE OF A BLOOD CORPUSCLE (A) AND PARTICLES OF COLLOIDAL GOLD (*f*, *g*, *h*)

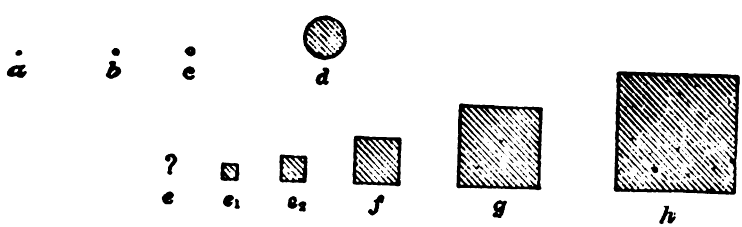


FIG. 2.—HYPOTHETICAL MOLECULAR DIMENSIONS

a—Hydrogen molecule. *b*—alcohol molecule. *c*—chloroform molecule. *d*—molecule of soluble starch. *e*, *f*, *g*, *h*—gold particles in colloidal gold solutions. Linear magnification, one to one million.

hydrogen, alcohol, and chloroform magnified one million times, and in *e, f, g, h,* a conventional representation of our colloidal gold particle under the same magnification. It will be seen at once that the smallest particles of matter observed under the ultra-microscope, while they are not actually of molecular or atomic dimensions, are of the same order of magnitude; the ultra-microscope has jumped the difference between the wonderful power of detecting a particle of matter containing only ten million million hypothetical atoms, the ultimate achievement of the spectroscope, and one containing, let us say, a few thousand. It may therefore be taken as an indisputable fact not only that matter can exist in particles infinitesimally small, but that the dimensions of these particles are perilously close to those assigned in calculation to "the inferential atom."

But the ultra-microscope has proved capable of throwing a demonstrational light upon the theory of atoms in quite another phase.

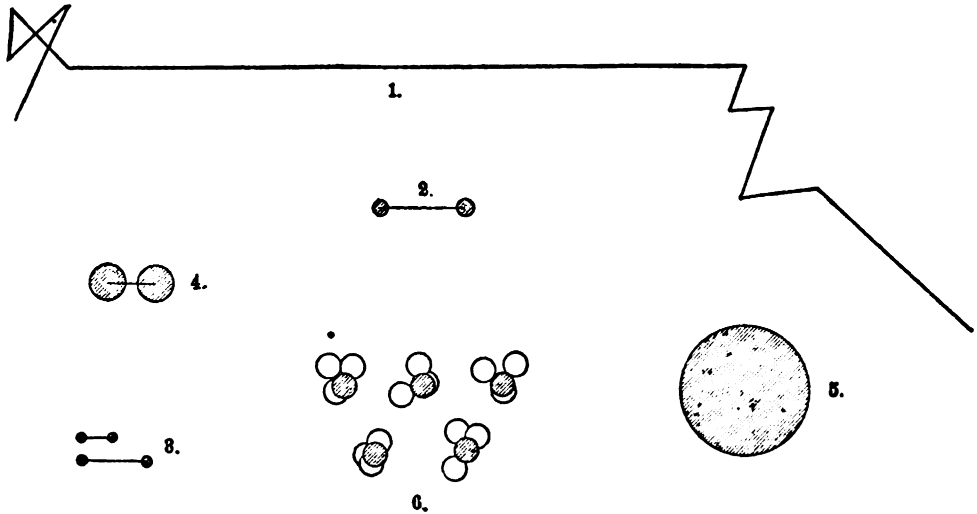
Quite apart from the ultimate particles of matter in themselves are the motions of them. Molecular motions infer molecules, and molecules infer atoms, and atoms infer the atomic theory. The kinetic theory of gases, therefore, which deals with molecular motions, is an integral part of the atomic theory and stands or falls with it. This theory assumes that a gas consists of a vast number of particles in constant motion, in constant collision with one another and with the walls of the

containing vessel. It assumes, too, that the particles travel in straight lines between collisions—in paths which are very long compared with the diameters of the particles concerned. It has been found possible by this conception to explain to a remarkable degree the physical properties of a gas and to predict successfully unknown relations of these properties. In fact, the kinetic theory of gases has been one of the most powerful engines of research ever devised for forwarding theoretical and experimental knowledge.

Turning, now, to the ultra-microscope and its revelations of infinitesimal particles, let us permit the original discoverer, Zsigmondy, to speak for himself of their properties.

"A swarm of dancing gnats in a sunbeam will give one an idea of the motion of the gold particles in the hydrosol of gold. They hop, dance, jump, dash together, and fly away from one another so that it is difficult to get one's bearings. This motion gives an indication of the mixing up of the fluid, and it lasts hours, weeks, months, and, if the fluid is stable, even years. The smallest particles which can be seen in the hydrosol of gold show a combined motion consisting of a motion of translation by which the particle travels from one hundred to one thousand times its own diameter in one-sixth to one-eighth of a second. . . ." Fig. 3.

But the hydrosol of gold is a liquid, and the kinetic theory, while it certainly is applicable to liquids, has,



Motion of Particles of Various Sizes and Kinds

1. Gold particles 0.01 μ in diameter.
2. Little spheres 0.5 μ in diameter.
3. Particles of gum gamboge.
4. Particles about 1.1 μ in diameter.
5. Particles 4 μ in diameter (without motion).
6. Brownian molecular motion according to O. Lehmann (arbitrary scale)

Linear magnification, 1 : 5000.

FIG. 3.

after all, mainly to do with gases. It is interesting, then, to know that Ehrenhaft has recently succeeded in extending the observations of these movements to gases. Thus, by striking an electric arc between silver poles, he has been able to produce a fine silver dust in the air, and on examining the dusty air with the ultra-microscope the suspended particles showed not only the motions of those in liquids, but to an exaggerated degree. Let the reader notice, then, that these particles, which are more or less of the order of molecular magnitude, possess the type of motion ascribed to molecules by the kinetic theory of gases, which is a theory dependent upon a theory. The type, we say, but there is more than this to it. It has further been shown that using the kinetic theory it is possible to deduce by calculation, and with a fair degree of accuracy, the motions actually obtained.

One of the most striking confirmations of the kinetic theory of gases is due to the work of Perrin. As everybody knows, the density of the air decreases the higher one goes; thus, at about six thousand meters above the surface of the sea the air is but half as dense. All this is understandable, theoretically, always theoretically, on the basis of the kinetic theory of gases. Now, Perrin has obtained a suspension in water of practically equally sized spherical particles of gamboge which, while exhibiting the characteristic motions referred to, gradually settle through gravity to the bottom of the vessel. On counting the relative numbers of these particles in layer after

layer from the bottom up, he has discovered that the number diminishes in miniature just as the density of the air diminishes and in accordance with the same law. Moreover, it looks as though these particles in arranging themselves acted reciprocally with the molecules of the solution; in other words, that they behave as though they were molecules themselves. However this may be, we adequately explain the decrease in density of the air on the theory that the air consists of particles, but in the experiment above referred to we find demonstratively that particles experimentally behave in just that way. By means of this unique instrument, then, and quite apart from any theory, we see, literally see, first that matter can certainly exist in particles more or less of the order of atomic magnitude, and, next, that these particles have the movements of the type and character that on *a priori* considerations we have been compelled to ascribe to particles which, chemically speaking, are ultimate.

But the ultra-microscope does not actually capture the individual atom. This achievement has been reserved for an instrument still more powerful and the most sensitive in the world.

In the competent hands of Rutherford, and in a research which will stand as classical in its refined and accurate experimentation, the instrument which has proved capable of this incredible feat is the electrometer.

In a paper of this general character the method of its accomplishment must be summarized, but its essentials are as follows: Everybody knows that radium gives off rays of three types—the alpha, beta, and gamma rays. The alpha rays alone concern us. On the basis of an enormous amount of knowledge it may positively be taken for granted that these alpha rays consist of positively charged flying particles, and that these particles are of atomic dimensions.[1] It is true that the considerations upon which this statement is based are to a certain extent theoretical, but these theories have stood impregnable to the attack of immense experimentation, and they have nothing to do with the chemical philosophy of the atomic theory. The alpha rays are charged particles, they fly through the air at the rate of about twenty thousand miles a second, and they are of atomic dimensions. The feat to be accomplished consists in catching them one by one; it transcends any analogy with which one might attempt to compare it.

Its success depends upon the power these particles have of rendering electrically conductible the air through which they tear their way. This property, by what might be called a trigger arrangement, Rutherford succeeded in magnifying thousands of times, until finally it became adequate. A diagrammatic representation of

[1] The proof of this statement is too extended for consideration here, but it may be found simply stated, *in extenso*, in a book by the writer, *The New Knowledge*.

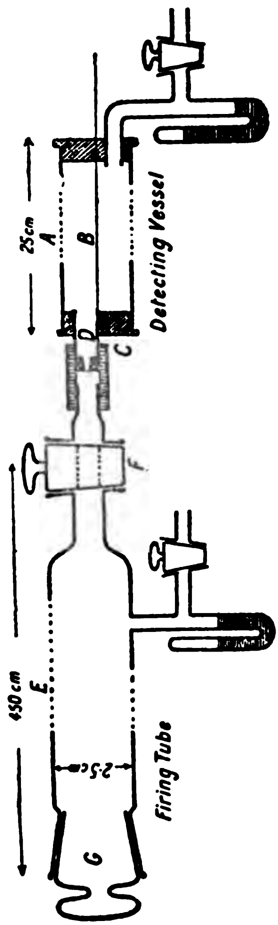


FIG. 4.—RUTHERFORD'S MECHANISM FOR DETECTING THE INDIVIDUAL ELECTRON

this apparatus will be found in the accompanying illustration, Fig. 4. Here in the text let us merely say that it is a·most attractive study in ballistics. There is a firing chamber containing the radium, and there is a target chamber containing the detecting arrangement connected with an outside electrometer, and between the two there lies a window of thin mica only one and one-half millimeters in diameter. In the firing chamber, infinitesimal projectiles from the radium fly through the window into the detecting chamber, and there, upsetting the electrical equilibrium of the air within, they cause a ballistic jump of the electrometer needle connected with it. One, two, three, four, at the rate of about thirty a minute, as they enter through the window, they cause one, two, three, four corresponding jumps of

the needle. Counting the atoms! It is, indeed, wonderful. If the reader is interested in watching a master at his work, let him read this research in its original presentation in Vol. 81 of the Proceedings of the Royal Society.

In this research he will find as well that Rutherford has laid his hands on an interesting confirmation of his work. Many people have seen, and will always remember, the scintillating stars of light that result on placing a bit of radium before a screen of zinc sulphide. It is like a swarm of fireflies on a dark night. Now, it has been suspected that the flashes of light were due, each of them, to the impact of an individual alpha particle, but no verifiable method existed for proving it. With the arrival of Rutherford's needle-jumps, however, the method arrives. If they really are due to the impact of individual alpha particles, then, under comparable conditions, they ought to correspond in number per minute with the needle-jumps of the electrometer. They do so correspond. Hence we have, now, not one, but two valid methods of identifying and counting the individual atoms.

But a critical reader at this point is likely to object: "These alpha particles of which we are speaking are 'queer' things. They may be of atomic dimensions, as you say, but how do we know that they are atoms? What are they atoms *of?*" This introduces Rutherford's crowning research.

In a research immediately following the one we have referred to he and Mr. Geiger showed on the basis of theoretical assumptions that the alpha particle was almost certainly an atom of helium. This does not interest us so much except in so far as it exemplifies the amazing validity of these atomic hypotheses in radioactive investigations. It does not interest us because in a research almost immediately following this again, and published in the *Philosophical Magazine* for February, 1909, he with Mr. Royds proves, not thinks—*proves* that this is actually, veritably, the case.

How he accomplished it even the layman may understand in the research referred to.

The whole achievement rests upon the possibility of blowing a small glass tube having walls less than one-hundredth of a millimeter in thickness; a tube of so thin a glass permits the alpha particles to fly through it, but resists a vacuum. Within this tube there is the radium firing its alpha particles, and surrounding it is a vacuous space, into which the alpha particles fly. After the lapse of two days, but growing stronger and stronger up to six days, there appeared in this vacuous space and between the electrical terminals within it a phosphorescent light which to the spectroscope lying in wait for it indisputably signified itself as helium. They proved that the helium was not in the glass used, was not due to any air-leak, was not in the mercury within the apparatus, was not due to any leak of radium

emanation; in fact, they proved indisputably, "up hill and down dale," that it was, and could not be anything else than, due to the alpha particles; that, in simple

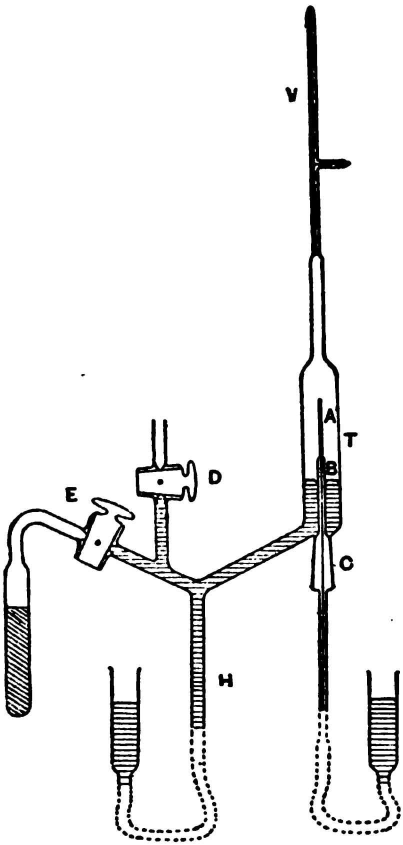


FIG. 5—RUTHERFORD'S MECHANISM FOR PROVING THAT THE ALPHA PARTICLE IS AN ATOM OF HELIUM

fact, a collection of discharged alpha particles is, *en gros*, helium.

The gas helium consists of particles; but are these particles atoms? Here follows the proof:

Dewar has shown, quite apart from theoretical considerations, and as a matter of fact, that one gram of radium produces a volume of 0.00000532 cubic millimeters of helium per second. Rutherford, by his counting method, has proved that this same gram of ~~helium~~ RA produces 136,000,000,000 alpha particles per second. But these 136,000,000,000 alpha particles constitute collectively the 0.00000532 cubic millimeters of helium. Therefore it follows by mathematical necessity that every cubic centimeter of helium under standard conditions contains 25,600,000,000,000,000,000 alpha particles. But this value is in remarkable accord with that which through a dozen different methods has always been held as the number representing the ultimate chemical particles in a cubic centimeter of gas. Therefore the discharged alpha particles in monatomic helium gas *are* the atoms. Fig. 5.

But helium in its physical properties is more or less like any other gas; therefore every other gas presumably consists of particles. But every other gas, generally speaking, will, under suitable conditions, become liquid and solid; therefore every substance of any kind whatever presumably consists of ultimate particles of chemical reaction.

I do not say that this remarkable demonstration of the atomic theory of matter is absolute. Not at all. Let us say, rather, that, taking into consideration the immense amount of inferential evidence of the atomic theory, together with evidence of this demonstrational character, we are sure of it as, for example we are sure that the rings of Saturn consist of satellites, which every sensible person, on the basis of the evidence, is willing to believe. We are almost as sure of it as we are of parentage, which, after all, is a theory. In simple consistency we should expect the teacher who introduces young gentlemen to organic chemistry without the atomic theory to introduce us to his "putative father"; the atomic theory is the father of organic chemistry.

At any rate, it permits us to speak of atoms and molecules without a blush. It enables us, too, to deprecate this business of writing text-books of elementary chemistry without the atomic theory. This has always been illogical and essentially absurd, and while after a certain fashion it may be accomplished, it has always worked to the serious hamperment of chemical instruction.

Modern knowledge has thus enormously strengthened the validity of the atomic theory, but it has not informed us, and does not teach us, that these atoms are actually ultimate in their nature or simple in their constitution. The reverse is the case. We are no more sure of the validity of the atomic theory than we are that these

atoms are actually highly complex. The modern idea of the atom is that it is, like the planet Saturn, made up of a nucleus related to satellites. We are sure that it consists in part of particles of negative electricity, we believe that it is made up in part of positive electricity, and we are inclined to think that there may be something in it quite apart from either. We shall never have a valid notion of the inner nature of the atom until we solve the nature of positive electricity, and about this, so far, literally nobody knows.

1910.

III

THE WHITHERWARD OF MATTER

"... melted into air, into thin air:
. . . .
... the great globe itself,
Yea, all which it inherit, shall dissolve. . . ."

THE beautiful old words forming the context of this quotation, spoken before Prospero broke his staff and drowned his book, convey to us a belief that is held by many of the great contemporary workers in discovery. It is not that stone and mortar crumble into dust, that "the lion and the lizard keep the courts where Jamsyd gloried and drank deep," and many another court and fane besides, it is that the dissolution to which the wizard referred, and which is now being divined anew through the wizardry of science, is a dissolution not of towers and temples, but of the very elements of matter of which they are comprised. It is that copper and gold, sulphur, carbon, and oxygen, and all the eighty-odd elements whose various combinations comprise the visible universe, are belike under the tooth of time, that slowly, inevitably, and altogether independently of us, they seem to be undergoing a progressive

degeneration to some condition of Nirvana—"melted into air, into thin air."

Our medieval forefathers saw nothing unreasonable in the thought that one element might be changed into another, that silver might be changed into gold or lead into silver; they called it *transmutation*. Our immediate fathers, however, believed in it not at all. To them the elements of matter were irrefragable, eternal substances; iron was iron, and gold was gold forever and forever. This was not with them so much a matter of dogmatic statement as of assumption; an assumption, too, that was wholly natural, for it was based on the fact that, do what they would, they could not transmute one element into another; they left out of account the consideration that what *they* could not do the elements of matter might be doing of themselves. Now the sons of our fathers, through careful experiment, observation, and deduction, are beginning to suspect that this unthought-of consideration portrays a fact, that the elements of matter are not eternal, but temporal, that there exists in every form of matter the process of its own decay, and this suspicion is gradually being crystallized into belief, into a new philosophy. But it is a philosophy that is so important to future generations of men in the way in which it will affect their actions and thoughts and beliefs, that I am going tc collect its present-day evidence, so that the reader, too, may be conscious of its force.

THE WHITHERWARD OF MATTER

It is some ten years ago, that memorable night when Becquerel found on a photographic plate the faint but legible signature of a new kind of rays that testified to the birth of a new science—the science of radioactivity. The science is thus so new that there has been much wondering and some skepticism as to whether it would *stand*—as to whether its theories were not fantasies and its "facts" but distorted interpretations of phenomena that would soon find a commonplace, dreary, and everyday explanation. Since the subject-matter of this paper lies wholly within this new science, it is expedient to say at the outset, advisedly and emphatically, that radioactivity has stood, though, as will probably appear from the new and remarkable facts to be adduced, it has not stood *still*. The fact is that radioactivity is singularly fortunate in the character of her devotees. The worker in this science must of necessity have so high a training, mathematical, physical, and chemical, that the science is hopeless of entrance to the tyro. The result it that there is little "fool's gold" in radioactivity; its facts are the pure metal.

The reader understands at least this about radioactivity: that there are certain substances that have the power of emitting, spontaneously emitting, peculiar rays. There are thus concerned with the subject two separate phases: there are the rays that are emitted, and there are the substances that emit them. Each phase has much to tell us concerning the whitherward of matter.

The substances that emit these strange rays are, so far as is known to-day, some twenty-five or so in number. While, with the exception of one or two, they exist, literally, in infinitesimal quantities which have never even been seen, much less handled, we have every reason to believe, first, that they *are*, and, next, that they are *elements* in the accepted sense of the term—elements as much as is gold or copper or oxygen. Considering what is known of radium and one or two of the others, the evidence for this is such that there is practically no peg left to hang a doubt upon. Concerning these ray-emitting elements, and owing to the fact that there have appeared in *Harper's Magazine* several articles on radioactivity, and owing, too, to the limitations of space, I am going to make this sweeping statement: that the innumerable facts of radioactivity in its vast literature throughout are explicable and correlatable only on one hypothesis, and that is that these ray-emitting elements owe their bizarre powers to their own decay, that they are transient, temporal elements, that their being is dying.

It is proper to make so large a statement only because of the character of the work and of the workers in radioactivity, and because, too, of the fact that while in the past these workers have been desperately assaulted they have practically silenced opposition, and that to-day there is among them a comprehensive unanimity of belief: radioactivity is due to elemental decay. Still, the

conviction that some elements are transient is so concerned, as the first cause, with the growing suspicion that all elements are transient, that I shall try to enforce it by giving the reader a glimpse of the correlating power of this conception. He will be impressed with this conviction in direct proportion to the time he expends in examining the diagram on page 46. This figure illustrates the summation of our contemporary knowledge of radioactivity; all radioactivity, it might almost be said, went to the making of this diagram. Here the reader will see that the radioactive elements are not isolated, unrelated substances, but, on the contrary, exist in several families. Next he will see that each family consists of a genealogical sequence of decaying elements, and in this connection he will look with particular interest at the horizontal arrows which are the most significant signs in radioactivity; they signify parenthood. Finally, and speaking generally, when with each one of these elements he can see what it decays out of, what it decays into, how long it lives, the kind of rays it emits, and when, in addition, we say that with most of them there is a pretty definite knowledge of their chemical characteristics, he will see that there is little in the way of a fulcrum for the lever of doubt to rest upon: *some* elements are transient. Between the thesis, however, that some elements are transient and that wholly different one that all elements are transient there is a wide hiatus. Can we build a bridge?

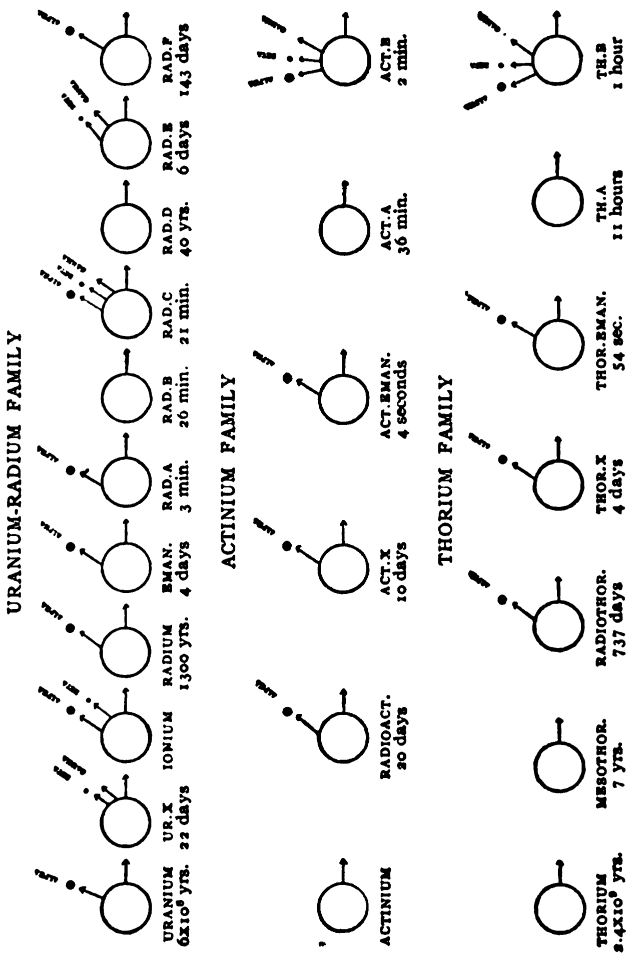


FIG. 6. THE DECAYING SEQUENCES OF THE RADIOACTIVE ELEMENTS

The radioactive substances, were it not for their ray-emitting power, would be in no sense extraordinary or peculiar; radium, for example, is so like the common barium that the cost of radium is in large measure due to the difficulty of separating one from the other. Still, they *are* queer substances, and had we nothing else to go upon, it would be quite unjustifiable to extend our deduction of their transiency to the ordinary forms of matter. But if we could prove that any one of these bizarre substances decomposed into an element of the ordinary type, if we could prove that one of the commonest of elements was capable of a degradation into another equally common, if we could show that radioactive substances and ordinary substances alike held constituents in common, that radioactivity is a mere accident, that ordinary substances, too, were radioactive, that ordinary substances, too, seem to undergo widespread degenerative changes, then with each increase of evidence our suspicion would cumulatively build itself up into conviction and belief.

This introduces the relation of a momentous research, the details of which are not even yet published in full, but the conclusions of which have been announced in advance—the story of the degradation of copper.

Away back in what might be called the medieval days of 1894 Rayleigh discovered in the atmosphere a hitherto unsuspected element, argon, and Ramsay subsequently and quickly followed this up with the discov-

ery of four others. These new elements—helium, neon, argon, krypton, xenon, all of them won out of the hidden places of the air—are definite gases that since that time have been prepared many times by many men; they have become as elements an integral part of science. They are all of one family, and are curious in this fact, that, except at a white heat, they appear to be incapable of existing in chemical combination with any substance whatever. The very word argon, the name of one of them, means lazy; they were all of them seemingly useless. Still, Ramsay headed his paper on the extraction of these substances with the old significant words of Sir Thomas Browne: "*Natura nihil agit frustra* is the only indisputable axiom in philosophy. There are no grotesques in nature; not anything framed to fill up empty cantons and unnecessary spaces." How prescient was this quotation will now appear. Not long after the isolation of these substances Dorn discovered that radium broke down or decayed into a substance which turned out to be a gas, and which has since been called the radium emanation. This gas out of radium belongs to the very family of rare gases in the air that Ramsay was so instrumental in discovering. This is shown in the fact that no matter to what drastic and powerful agents the radium emanation is subjected, it is impossible to destroy it or to alter it; in this fact it perfectly resembles these rare gases. Unlike them, however (and it is a strange thing to say, but perfectly true),

while it is impossible to decompose it or to alter it, it is decomposing of itself. Half of it has died some four days after its birth, and during its short but strenuous life it *evolves nearly three million times as much heat proportionately as arises from any chemical action known to man.* This is a tremendous fact, determined by strict experiment, and quite apart from any theory. The radium emanation is the most potent substance in nature. Its enormous store of energy is given out through its decay, and it decays into what? Into *helium,* the first of these curious, inert elements that Ramsay discovered. This was proved in 1903 by Ramsay and Soddy; since then their work has been repeatedly verified by other men, and to-day there is simply no shadow of doubt but that it is a fact. This discovery that the gas known as the radium emanation breaks down into helium initiates the beginning of a new epoch. It takes us out of the radioactive substances into a substance which is not radioactive at all, and which is a well-known element. The spectrum of the radium emanation had been mapped, and the spectrum of helium was well known; and, consequently, it was the first thoroughgoing demonstration of the fact that one element could be changed into another that was common, that transmutation of matter was proceeding, and that the alchemists were right.

But the possession on the part of the radium emanation of so enormous a store of energy suggested to Ram-

say that even though it could be collected and handled only in the most minute quantity, it might be utilized, nevertheless, to bring about chemical changes in matter with which it was in contact; and so he placed it in—*water*. The results have shaken science the world over. First, something happens to the emanation: it appears that the emanation, instead of decaying into helium, as it does when dry, in the presence of liquid water decays into *neon*, the second of this interesting series of gases discovered in the air, and a form of matter wholly distinct from helium. Furthermore, when in the water containing the radium emanation there is dissolved some copper sulphate (blue vitriol) the resulting gas is neither helium nor neon, but the third member of this family, *argon*. It appears, then, that this gas, this radium emanation, which it must be said has a good claim to the name of element, decays or becomes transmuted not into one other element, but into three, according to its surrounding circumstances.

Matter is capable not only of transmutation, but of selective transmutation. Grass, as we all know, is capable of transmutation into sheep or cow or horse according to circumstances, but such a transmutation is a building process. The emanation transmutation is, on the contrary, a process of decay, and, infinitely more than this, it is the process of the decay of an element. It is interesting, and there is a dramatic consistency about it, too, that these substances cast upon the flood

of research before 1895 should, after these many days, return in this momentous manner to the discoverer's own hands. *Natura nihil agit frustra,* indeed! Fig. 7.

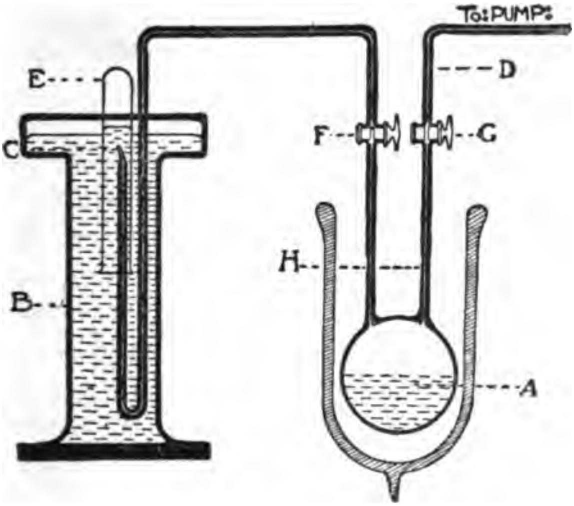


FIG. 7—RAMSAY'S APPARATUS FOR STUDYING THE ACTION OF THE RADIUM EMANATION ON WATER

Water emanations in A are surrounded by liquid air in H. The gases are collected in E

But the vagaries of this strange gas do not end with its decay; there is its effect upon the water. Everybody knows that water consists of two volumes of hydrogen combined with one of oxygen. Now, water in the presence of the radium emanation breaks down into these constituents right enough, but there is discovered in the resulting gas *too much hydrogen:* there is a greater amount of hydrogen in the gas than the water propor-

tionately contains; sometimes from ten to twenty per cent. too much. Whence the excess? This is a mystery still to solve; it is an unquestionable fact that has been verified by several men, and I cite it here as highly remarkable, though I shall refer to it again in another connection.

Again, there is the action of the emanation upon the water that contains, dissolved in it, the copper sulphate. One hesitates almost to state the result, but here it is: in the solution of copper sulphate in contact with the minute quantity of the gas from radium there appear both sodium and lithium. The sodium, it is barely possible, though by no means probable, is derived from the substance of the glass containing vessel, but the *lithium*, according to Ramsay, is undoubted. It is not in the glass, the air, the water, the emanation, or the copper, to begin with; and yet, to end with, there it is in small but indubitable quantities. The conclusion seems forced upon us that it is a product of the decay of the copper.

If the degradation of the radium emanation into helium opened a new scene in the drama of the world's advance, the discovery of the degradation of copper opens a second, for it is the discovery that a common element of every-day experience can decay into another almost equally common. It leads us to ask whether the potent radium emanation may not simply accelerate, by catalysis, a process that is always and everywhere in operation—that copper is always decomposing—and

that since copper is in no fashion a peculiar or esoteric element, whether what happens to copper may not be taking place with lead, carbon, sulphur, and every element known to man. It is particularly interesting in this connection to note that some of the uranium copper ores of Colorado contain minute traces of lithium.

It is for future research to establish the whether or no of this idea of the universal degradation of matter into simpler forms, but there is much in recent radioactivity to suggest that it is veritably a fact. So far, only the substances that emit the rays have been considered, but the rays themselves have something also to tell us.

The alpha rays, for example, are streams of positively electrified particles of atomic dimensions that are continuously and persistently expelled by most of the substances appearing in the diagram. They are accepted as little projectiles that are shot out from radioactive substances at the rate of from ten to twenty thousand miles a second, and the energy by which they travel at this amazing rate apparently arises from the breaking down of the atoms of which they are a part; in other words, the transmuting degradation of radioactive substances is due to the expulsion of these particles; they are thus the *evidence* of elemental decay. It is by means of their effects that they can be strictly followed in their flight.

It seems, and we did not know this before, that these

little particles, shot out from whatever radio-substances there may be, are all *alike*, that their sole difference seems to be one of mere velocity—that no matter what gun is shooting them, so to speak, the bullets are all of one caliber and one make. This is sufficiently interesting, for it leads us to see that there is a constituent common to all radioactive substances; if now we could prove that these same particles, which, as we have said, are the evidence of elemental decay, occur as well in ordinary substance, our suspicion of a universal decay would be just so much enforced. The interest thus deepens and becomes highly significant when the fact is associated with the results of a research recently published by Prof. J. J. Thompson. He has shown that in the intense electrical field generated in a Crookes tube substances give off particles charged with positive electricity, that these particles are independent of the nature of the gas from which they originate, and that they are of two kinds: one apparently identical with the hydrogen atom, and the other with these very alpha particles that are projected normally from radio-substances. What is the teaching? Substantially this: stated in plain terms, he means us to infer that all the elements with which he experimented broke down, or were decomposed, in part, into the well-known element hydrogen. His work is thus not only just as wonderful in its nature as that of Ramsay, but, however different were his methods, it leads to the same conclusion—that the

every-day, ordinary elements of matter are capable of a transmuting devolution into simpler forms. Furthermore, it is directly confirmatory of Ramsay's result; for, as I have stated above, Ramsay found that pure water in contact with the radium emanation yielded an *excess*

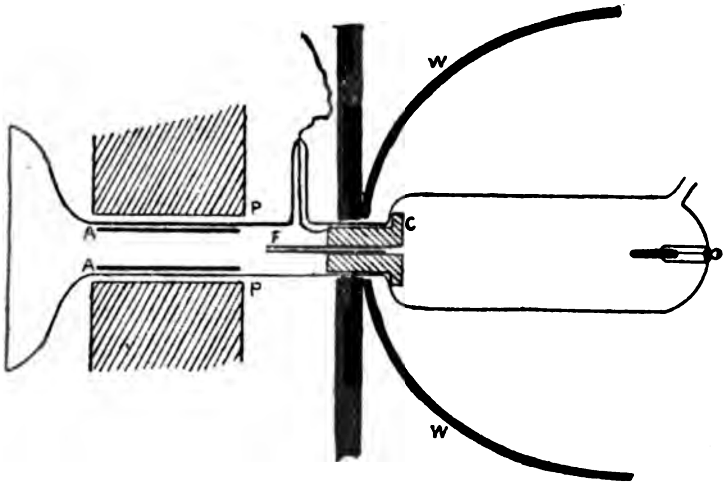


FIG. 8.—THE CROOKES TUBE WITH WHICH THOMPSON PROVED THAT HYDROGEN AND ALPHA PARTICLES COULD BE TORN OFF FROM OTHER ELEMENTS

of hydrogen—this same element. But Thompson's research has a wider scope. He shows us that the ordinary forms of matter can emit, in addition, the very same particles (alpha rays) that were thought to be a constituent peculiar to radioactive substances. So far, then, as the possession of alpha particles is concerned there is nothing peculiar in radioactive substances; they

are contained potentially in matter of every kind. But if they are the product and evidence of elemental decay, then, since they occur in ordinary matter, we should be justified surely in suspecting that this decay is universal. If, now, we could prove that matter of every kind not only contains them, but emits them, we should, in accordance with our present ideas, no longer suspect, but *know*, the universal degradation of matter. This today can be done only presumptively, but the presumption is strong.

The loss of effective range suffered by the alpha particles is determined by the distance from the emitting body at which they cease to affect a photographic plate or a phosphorescent screen, or at which they cease to render the gas a conductor of electricity. It is interesting that they cease, all of these effects, *at the same distance.* In this cessation of the action of these rays upon the foregoing detectors there is much that is significant. For, think of it! Flying out through matter, at a certain distance, at the very culmination of their powers to affect these detectors, they lose them. Phosphorescent, photographic, and ionizing powers alike absolutely, abruptly cease, and the alpha rays assume the mantle of invisibility. Whither they go and what becomes of them no man at the present day can tell. Through 0.0037 of a centimeter of aluminum they will affect a photographic plate; through 0.004 of a centimeter they will affect it not at all. The whole present-day interest

in the alpha rays concentrates in this additional and truly significant fact, that at the instant of their vanishing beyond the power of man to pursue they still possess sixty-four per cent. of their initial velocity and forty-one per cent. of their initial kinetic energy. The critical velocity below which they cannot be detected is some fifteen billion centimeters a second—a very considerable pace. Now for conclusions: Were these particles not possessed of an initial velocity a trifle greater than this value we should not have been able to find them; and to-day we should not only be ignorant of their existence, but ignorant as well of radioactivity. Furthermore, were ordinary substances, matter of every kind, emitting these particles at any velocity below this very considerable pace, they would be wholly beyond the power of present-day apparatus to detect. Now for inferences: We know that ordinary matter potentially contains these particles; we know that they are detected flying off from radioactive substances solely through this slight excess of velocity; and we know that, with the exception of their ray emissions, radioactive substances are chemical elements in no wise peculiarly different from ordinary matter. There is, therefore, a strong presumption that ordinary matter is continuously emitting these particles, that, in consequence, it is undergoing degradation, and that we are in ignorance of it only through the limitations of our apparatus. Finally, it leads us also to think that the only essential difference between radio-substances

and ordinary substances lies in the velocity of the particles they eject.

This is supported by a very curious and interesting fact, that the reader may discover by re-examining the elements in the diagram on page 46. He will notice that some of the elements in these decaying sequences change without the *perceivable* emission of rays; they are undergoing so-called "rayless changes." In this table he may thus see, changing yet "rayless," thorium, thorium A, actinium, actinium A, radium B, and radium D. The discovery that some forms of matter may undergo degradation without perceivable emission of rays is due to the mere accident that in a decaying sequence of elements they happen to lie sandwiched in between those that do emit perceivable rays. The strong probability is that this "rayless" condition is only apparent, not actual, and due to our lack of means to detect the rays. At any rate, the fact that ordinary matter does not perceivably emit these rays is no sign that it is not degrading, for here are certain substances that do not and yet are.

From still other contemporary sources there arrive similar hints of universal degradation. Thus, there are the delta rays, about which probably the reader now hears for the first time. It is likely that these rays will in the future play a preponderating rôle in radioactive investigations. In their nature they appear to be slow-moving electrons (slow beta rays) that fly out from

ordinary matter of whatever sort when it is struck by other radiations; they are thus *secondary* rays, target-emitting rays. Among the many interesting facts connected with these radiations is one of extreme significance. The rays that are bombarding any mass of substance may be of any type—alpha, beta, gamma rays, X-rays, or even light rays; it makes no difference—the rays which the substance under bombardment emits are its own rays, delta rays. And these rays all proceed out at practically the same speed, and at a speed, too, which is quite independent of the character and energy of the impinging particles that cause them. The delta particles, then, cannot be simply particles torn off from matter by the particles that strike it; if they were, their energy would certainly be in some way proportional to the particles that did the tearing. What, then, can they be? Let me illustrate this by an analogy: Suppose that there is a piece of paper slowly smoldering into decomposition, and suppose that I touch a lighted match to it. The smoldering paper is destroyed with a sudden whiff of flame. Now it is obvious that the flame of the paper does not depend on the kind of a match I use, nor, if it is a lighted match, on how big is the flame of the match. The flame of the paper is due to the energy of its combustion, which is slowly proceeding, anyhow. The lighted match is simply a "trigger" that lets it suddenly loose. So it may be with the delta rays: they are the "flame" of an ordinary atom

which, anyhow, is slowly decomposing; the impinging particles are "the lighted match." But how do we know that the atom in the first place is "smoldering"? We have evidence for this in a research by Prof. J. J. Thompson, which has proved that common substances, such as the alkali metals, the liquid alloy of sodium and potassium, and ammonium amalgam, all emit these delta rays to a small but definite amount without any ray bombardment whatever; they will emit them even in the dark and, in certain cases, in a vacuum. The ray-emitting power of the common metal potassium is actually one one-thousandth of uranium. The delta rays, then, tell the same story in a different way—the story of the universal decomposition of matter. The lithium that Ramsay says that he has obtained from copper, on facing it with the radium emanation, appears to be just the "ashes" of the copper. An interesting contemporary discovery that is confirmatory of this elemental decomposition, as it is exemplified in the energy emitted through it, tells us that when a plate of lead and a plate of zinc are respectively exposed to the same shower of X-rays there is twice as much heat produced in the lead as in the zinc. The only apparent solution of this interesting fact lies in the supposition that the heat is due to the internal store of the atom's energy as it is liberated through the atom's disintegration under the bombardment of the X-rays.

So, at the conclusion of our paper, it appears that

Ramsay's announced achievement in degrading copper into lithium need not be received with incredulity, need hardly excite surprise, for it is supported by many diverse facts of modern knowledge. It appears that the elements of matter, that we have taken for granted were so immutable and enduring, are transmutable into simpler forms.

That the elements are not only transmutable but transmuting is not so plain, but there is much to be said for it. Those rare gases, helium and its congeners, that we have found to be the by-products of this elemental decay, are found in the air to the extent of nearly one per cent.; they have been found, likewise, in all the places in the earth where gas collects. They are found in the gases collected from mineral springs and from volcanoes; the very rocks of the world on being heated expel them; they may be extracted from the pores of the soil, and recently they have been discovered as a general constituent of natural gas. It is reasonable to suppose that they appear in all these diverse places as a by-product of the earth's decay. We are additionally ready to accept this when we find that the gases so collected, together with the earth itself, are radioactive, for radioactivity is the very sign and seal of disintegration. Finally, when we find that, through the radioactivity of the materials of the earth, there is continuously being evolved an amount of heat far, far in excess of that required to maintain the earth's loss of heat by

radiation, and to keep its temperature constant, we perceive not only the disintegrating dissolution of matter, but we begin to suspect as well a fatally determined acceleration of it to some one time "in the which," to use the words of the apostle Peter, "the heavens shall pass away with a great noise, and (στοιχεῖα δὲ καυσούμενα λυθήσεται) the elements intensely heated shall be broken up, and the earth and the works that are therein shall be burned up."

1909.

IV

X ON THE CHEMICAL INTERPRETATION OF LIFE

THE new science of radioactivity has had a stimulating effect upon subjects of natural knowledge far removed from physics and chemistry. It has set men thinking that possibly, in branches of knowledge wholly different, long-established doctrines and concepts might not have the impregnability that appeared—that, in fact, it was time for the keepers of the house of natural knowledge to have a general house-cleaning. Radioactivity has to do, primarily, with matter, but as the concomitant term for matter in the mind of nearly everybody is "life," revelations in the one have inspired reinvestigation in the other, and now in every tongue voices are again calling the questions: What *is* Life? Whence came it? and, Whither does it go?

But in all this scientific imbroglio there has appeared no basis of agreement whatever. This inability of thinking men to arrive at, at least, some kind of a concordat appears in the very definitions of the life that they discuss. Life is self-movement; life is sentiency; life is the sum of the forces that resist death; life is the principle of individuation or the power that unites a given

all into a whole; life is the continuous adjustment of internal to external relations. When one examines closely into these most diverse definitions, one sees that their only agreement lies in an unconscious or subconscious evasion. The minds that formulated these definitions defined the properties and powers of a thing, a *something* which they were unwilling or too tender to postulate. These properties and powers defined above must *inhere* in something, must they not?—must be possessed by something—and this something behind the definitions describing its powers is what men mean by "Life." But if "Life" is an existent entity ruling over the gross matter which it inhabits there ought to be some evidence of it, something other than "the evidence of things unseen," and hence any paper dealing with the relation of "Life" to the body ought to proceed first to answer the question, not what is "Life," but where is "Life"?

Hitherto this quest has been deemed wholly within the province of the biologist, and through it he has found a beautiful, wonderful mechanism—and nothing more. It seems to be accepted by the great body of present-day biologists that there is in the living body no evidence of an inner god, and this doctrine, under the name of mechanism, now blares its challenge through all the uncouth terminologies of modern science. But a mechanism appears to imply a mechanic, and so a few believe that though they cannot see him there abides

secretly in the living being a maker and worker of the machine—a master mechanic—called "Life." Now chemistry looks deeper than biology, and it may be, then, that through chemistry, and within the mazy configuration of the body's very atoms, we may behold the face of the workman.

The first obvious thing about any "living" being is the substance of it—the pounds of material of which it is composed. Is there anything about the "make" of this matter or material that is esoteric, anything that might show the action or the presence of this "Life"? There is this about the substances that constitute a "living" being: there is the bewildering complexity of them, and their lability or irritability. These two characteristics of "living" matter are so salient as to appear at first sight transcendental. But this is not so; the complexity of these substances is due chiefly to the carbon atoms that in such large measure comprise them. There is nothing transcendental about this power of the carbon atom; it is a long-known, perfectly recognized fact of general chemistry—"vitality" has nothing to do with it. As for the lability of "living" matter, it is due in the main to the nitrogen atom, the most powerful, mutable entity in nature. There is nothing occult about it; in fact, the restless character of the nitrogen atom is much more pronounced in guncotton, nitroglycerin, and in gunpowder than it is in the proteids of the animal tissues. There is thus about the two most

salient characteristics of "living" matter nothing that is mysterious, ultra-knowledgeable, or extra-scientific. As for the intrinsic nature of these substances, there is this to be said: that when the chemist can make in his laboratory bodies identical in composition and in property with substances of vegetable or animal origin, there is no longer any mystery in these substances *per se—i. e.*, except in so far as everything is mystery. He has been able to do this, and every year brings its increasing swarm of synthesized natural products. To take a few examples: he has recently made in his laboratory the indigo of the indigo plant; vanillin of the vanilla pod Fig. 9; chrysin of poplar buds; apigenin of parsley; luteolin of the broom plant; ficetin of yellow cedar; quercetin of sumac; kämpferol of the blue larkspur; galangin of the galanga root; camphor of the camphor-tree, and even nicotine of tobacco. Others have been made in the laboratory that are the products of the animal organism—dozens of compounds—such as cystein and cystine, leucine, indoleacetic acid, and even turacin, the red pigment of the feathers of the plantain-eating birds. Searching through the nooks and crannies of living things, and, of course, taking the easier ones first, the chemist is gradually building up by the artificial means of his laboratory the natural substances of the animal and the plant.

For the synthesis of many substances the difficulties for the nonce are too great. He does what he can.

FIG. 9.—CAKES OF CRUDE ARTIFICIAL VANILLIN

The photograph represents an amount of vanillin (500 lbs.) equivalent to that contained in a carload of vanilla beans

Thus, if he cannot synthesize the substance, he may determine its constitution, and if he cannot determine its constitution he may at least isolate it. Thus, with the proteids, those indefinitely complex and mobile constituents of living tissue; these substances are not the beautiful, precipitable, separable, crystalline substances of the inorganic world, but are, on the contrary, "messy" gelatinous mixtures called "colloids." Out of the muck of this enveloping and interpenetrating mixture he drags his quarry, some one chemical substance, and, having it once free from defiling impurity, he has all the reasons of his past successes for believing that he will ultimately analyze it and synthesize it. With the proteids success proceeds apace. Emil Fischer, of Berlin, his students, and his emulating colleagues the world over, have succeeded not only in isolating proteid bodies, but in splitting them down into determinable "cleavage products," and have, as a matter of fact, actually succeeded in synthesizing one or two of the simpler type. Just so surely as the years pass, so surely will chemistry devour the mystery of living matter. For, what is the teaching of these thousands of laboratory syntheses? Just this: that there is no substance in plant or animal that does not lie prone under the domination of chemical science; that there is visible in these substances *per se* no entity, no principle, no power called "Life."

There is a certain objection that will be, has been,

urged against this conclusion of science. According to the objector: "You have pointed out certain atomic configurations existing in a living being that you can reconstruct in your laboratory, and I am willing to admit that you may accomplish this to an indefinite extent, but *are your laboratory methods those of Nature? And, if not, may not Nature's methods be due to a presiding entity?*" This objection has force; *it is true:* the laboratory methods of organic synthesis have little relation, have barely an analogy with the processes that go on in the living organism. The chemist uses violent reagents, and he uses fire; the plant, on the contrary, proceeds to the elaboration of its complex compounds in the smoothest, mildest way, and within a degree or two of temperature. The action of the plant seems transcendental. But not at all; if the chemist cannot imitate the plant process, he has clues, several of them, to the mystery.

One of these clues is catalysis, the discovery of which is transforming the face of chemical science. There exist in the bodies of plants and animals substances that bring about chemical reactions by their mere presence—by merely being there; substances that dictate what reactions shall, or shall not, take place therein; these substances are, for the most part, called enzymes. Thus, there is diastase from barley malt, which, like the ptyalin of the saliva, has the power of transforming starch into sugar; there is pepsin in the gastric juice which decom-

poses insoluble albuminous food products into a soluble form; there is invertase from "yeast," which has the power to transform 200,000 times its weight of sugar into invert sugar, quite a different substance; there is rennet, which will transform 400,000 times its weight of soluble casein. Such substances, the most of them, remain quite unaffected by their valuable exertions. All the kinks and corners of the bodies of plants and animals have these efficient little chemical substances, which, at the right time and the right place, exert their powerful "personality" upon the juices of the organisms to their consequent reaction. Very remarkable are some contemporary discoveries of this type. There is the substance secretin, which, formed in the lining of the small intestine, passes into the blood, and when, in the course of its circulation, it comes into the pancreas, it causes by its mere presence the secretion of the pancreatic fluid, which itself contains an enzyme; secretin is the enzyme of an enzyme. There are other substances elaborated in the body of the prospective mother, which, introducing themselves into the blood, determine, again by their mere presence, the changes necessary for the proper emplacement of the unborn child. There are still others which, formed in the tissues of this child, will, when they pass into the blood of the mother, evoke in the mother's breast, at the proper time, the nourishment for the child when born. Organic substances such as these enzymes that do not, apparently, enter

into a reaction, but, instead, cause it, are known as catalysts, and the process as catalysis. The presence of these influential substances in the "living" organism is one of the factors that explain, in large measure, the ease with which reactions take place therein. This action is, at first acquaintance, so mysterious that it seems peculiarly a "vital" action; one thinks that, because it is outside the possibility of representation by chemical equations, it falls outside the scope of chemical inquiry. On the contrary, though, catalysis is as wide as chemistry. To illustrate this: An extract from the supra-renal glands has an astonishing power to augment the blood pressure. Out of this extract there was isolated a definite substance named adrenalin; its constitution was next established; then its laboratory synthesis; and now, made out of coal-tar, it may be bought in the markets of the world with a physiological value equal to that of the natural product. This blood-pressure-raising principle, so valuable to the modern surgeon, is not a transcendental mystery; it is a thing to study.

The catalytic actions of recognizedly inorganic substances having no relation to life it would take a dictionary to chronicle; they have even a wide industrial application (*vide The Chemistry of Commerce*, by the writer).

If the chemist does not yet understand the innermost heart of catalysis (which he certainly does not), he never-

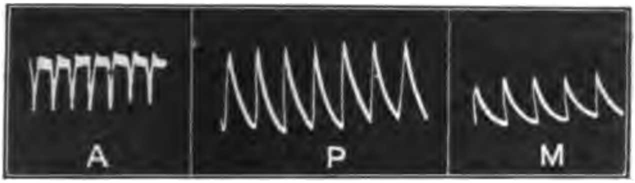


FIG. 10.—UNIFORM RESPONSES IN (A) NERVE, (P) PLANT, AND (M) METAL

The normal response in nerve is represented "down." In this and following figures, (A) is the record of responses in animal, (P) in plant, and (M) in metal.

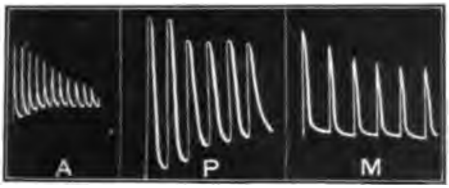


FIG. 11. — FATIGUE (A) IN MUSCLE, (P) IN PLANT, (M) IN METAL

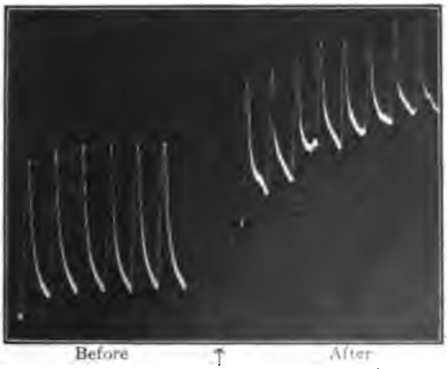


FIG. 12.—DEPRESSING EFFECT OF KBr (10 PER CENT.) ON THE RESPONSE TIN

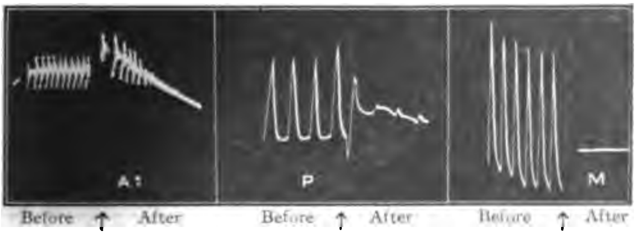


FIG. 13. — ABOLITION OF RESPONSE IN NERVE, PLANT, AND METAL BY THE ACTION OF THE SAME POISON

The first half in each set shows the normal response, the second half the abolition of response after the application of the reagent.

theless understands fairly well the rules of its action, and to such an extent that it is rapidly being brought under the mathematical formulation of natural laws. Naturally, then, he does not regard these "vital" transformations with the awe of his scientific forebears—they are Chemistry, not "Life."

But there are substances known to general chemistry that act in the reverse way to a catalyst; these are negative catalysts, whose mere presence will retard or bring to a full stop many chemical reactions. When, then, corresponding to these substances already known in the outside world, the chemist finds in the "living" body anti-rennet, anti-pepsin, anti-diastase, anti-trypsin, and other negative catalysts, he feels himself by no means in the presence of a transcendental entity; he is in the presence of a chemistry that is as wide as matter.

Were it not for the limitations of space, we should discover that just as the search for "vitality" through certain activities of "living" matter has led us to chemical catalysis, so should we be led through others to photochemistry, and through still others, such as excitability, reproduction, and nervous action, to general physical chemistry. Wherever we look at a point in all the vast expanse of special properties connected with "living" matter, that point resolves itself into a chemical mechanism, and into nothing else.

One of the phenomena of "living" matter, peculiarly "vital" in the hyper-mechanical explanations afforded

for it, is "response," the power of an animal or a plant to respond to a stimulus. The muscles move in response to a nerve, the retina responds to light, the sensitive plant to a touch, and so on. This power to respond, or irritability, is one of the signal manifestations of "Life." It has been discovered that one of the best methods of measuring this response is electrical in its nature, and through the elaboration and perfecting of this method some surprising information appears. Just as animals and plants respond to a stimulus, so do metals and other inorganic substances. Furthermore, just as animals and plants become fatigued, and refuse to respond under a stimulation that is continuous, so do metals. Living beings and metals are alike, too, in their action under stimulants, substances that have the faculty of exalting this power of response; they are alike in temporarily losing this power under the action of anesthetics; they are alike in the diminution of the intensity of this power under the action of depressants like potassium bromide; they are alike in losing it permanently under the action of poisons; and in a multitude of other similitudes it has been shown that this whole business of the power of an animal or a plant to respond to stimuli is a function, not of "Life," but of matter, and with the out-and-out proof of this has passed away the necessity of postulating for it any unknowable and arbitrary "vital" force. Figs. 10, 11, 12, 13.

But outside the substances of "living" things and

their special activities, there are the *forms* of them—so different from the substances of the mineral world that they seem of a wholly different order. Persistent investigation, however, tells a different story. The difference between the organic and the inorganic worlds is by no means so accentuated as appears. Thus, from crystallography, we hear of "sterile" liquids containing substances in solution that require the presence of a crystalline "germ" to bring about the "birth" of crystals—curiously biological language for crystallography to indulge itself in unnecessarily. We hear of veritable artificial tissues that simulate in a marvelous way the cellular tissues of the living plant, even to their division and segmentation (Fig. 14). We hear of multitudes of mineral forms, artificallyconstituted, that betray the most manifold likeness to the beautiful forms of the smaller organisms—artificial amœbæ, diatoms, radiolaria, and many others, made out of mineral silicates. The studies of the relations of mineral forms to the forms of living organisms constitute a new science—plasmology. This science is very new, but already it tells us, and in no uncertain tone, that the form and structure of "living" things are due solely to the interplay of physical and chemical forces, and that they are in no fashion the expression of an inner "Life"; that even man, in form and action so divine, is, speaking physically, just as much so, and no more, than the veriest water-worn rock of ocean. Figs. 15, 16.

Then, again, there is the energy of the "living" body. If there is in the body any presiding entity, it must be, from the very definitions of this "Life," a working entity, and hence there is entire propriety in expecting evidence of its existence in some difference between the income and the outgo of bodily energy. It may be that "Life" would add to the bodily energy, it may be that it would subtract from it, but simple reasonableness demands that if it is as "energetic" as defined, it ought to alter it. But refined experimentation denies the evidence. Professor Atwater's investigations into nutrition have shown in the most convincing manner that the body derives all its energy from the food consumed, or, if the food is insufficient, from its own body-tissue. The outgo of energy is exactly equal to the income, and it may be regarded as established by his experiments with the respiration calorimeter that the law of the conservation of energy holds for the animal body. Rubner is still another investigator who has done yeoman service in proving this same fact. There is, therefore, in the employment of energy by the "living" body no hint whatever of the existence of a "Life." It is positively what it ought to be, were the body solely a mass of matter undergoing chemical change. Fig. 17.

Finally, there are other functions of a living organism, general functions, such as movement, reproduction, assimilation. May it not be that one or some of these are extra-chemical? For example, there are the parallel

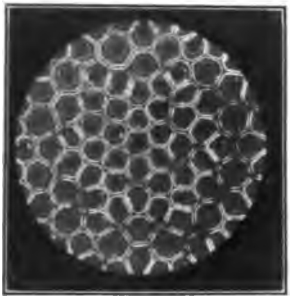


FIG. 14.—TISSUE OF ARTIFICIAL CELLS IN GELATIN (ST. LEDUC)

FIG. 15.—SALICYLIC ACID IN PRE-CRYSTALLINE STATE SHOWING UNIPOLAR AND MULTIPOLAR CELLS WITH THEIR NUCLEI (VON SCHRAN)

FIG. 16.—ARTIFICIAL AMŒBA FORMED OF SILICATES (HERRERA)

processes of constructive and destructive metabolism, the mysterious weaving and unweaving of our bodily garment. Out of the depths of our physical being there arise, unceasingly, complicating molecules of substance; there are islands of atoms, kingdoms of atoms, and, finally, as worlds of atoms, these protoplasmic molecules break into their disintegration products; all this over and over again, and so we "live" in the stream of energy produced therethrough. The inorganic world has many analogies to this: crude little analogies, but such as are sufficient to show that this upbuilding and unbuilding in a stream of energy are by no means peculiar to the "vital" process. It may be that the light that is shining on this page is emitted by a gas-mantle. This mantle consists of 999 volumes of thoria to 1 volume of ceria. This speck of ceria is absolutely essential to the light emissivity of the mantle. Its powers, apparently, lie in this, that in the burning lamp the ceria is constantly taking up oxygen from the air which it hands over to the gas for burning, producing thereby the incandescence of the enveloping thoria; oxide and peroxide, oxide and peroxide, the ceria is incessantly building and breaking throughout the life of the lamp. If this explanation of its powers is true, it gives us the simplest example of this constructive and destructive metabolism.

The great mystery about this process has always been the constructive phase of it, the growth of "living" mat-

ter through assimilation. I shall take space to examine this assimilation, for it has always been the *bête noire* of the mechanists. Since assimilation is a phenomenon of all "living" matter, it simplifies things to examine one of the elemental forms of "Life."

There is an acknowledgedly "living" thing—a bacterium—which, for convenience, is called A, and it is examined at the time T. At this *precise moment* it consists of n substances chemically defined. It exists in a liquid medium, beef broth, which contains m substances, also chemically defined. Is there anything more? Nothing that we know of. Between these $n + m$ substances certain reactions take place, and at the end of an instant, T_1, the bacterium A is changed; it now consists not of n, but of n_1 substances. Now, behold a miracle: At the end of a certain time this changed bacterium undergoes a succession of further changes, and finally divides into two bacteria, B_1 and B_2, each of which at the time T consists of n substances, the same substances as are contained in A at the time T, but doubled in quantity. Nor is this the end of the process, for, remaining in the same medium, these two bacteria B_1 and B_2 change just as A did, and, at a given moment, they too divide, so that there result four bacteria—C_1, C_2, C_3, and C_4—also at a given instant containing these same n substances as A at the time T, but quadrupled in quantity. Finally, as the result of the indefinite successive division and redivision of C_1, C_2, C_3, and C_4, we have the broth swarming

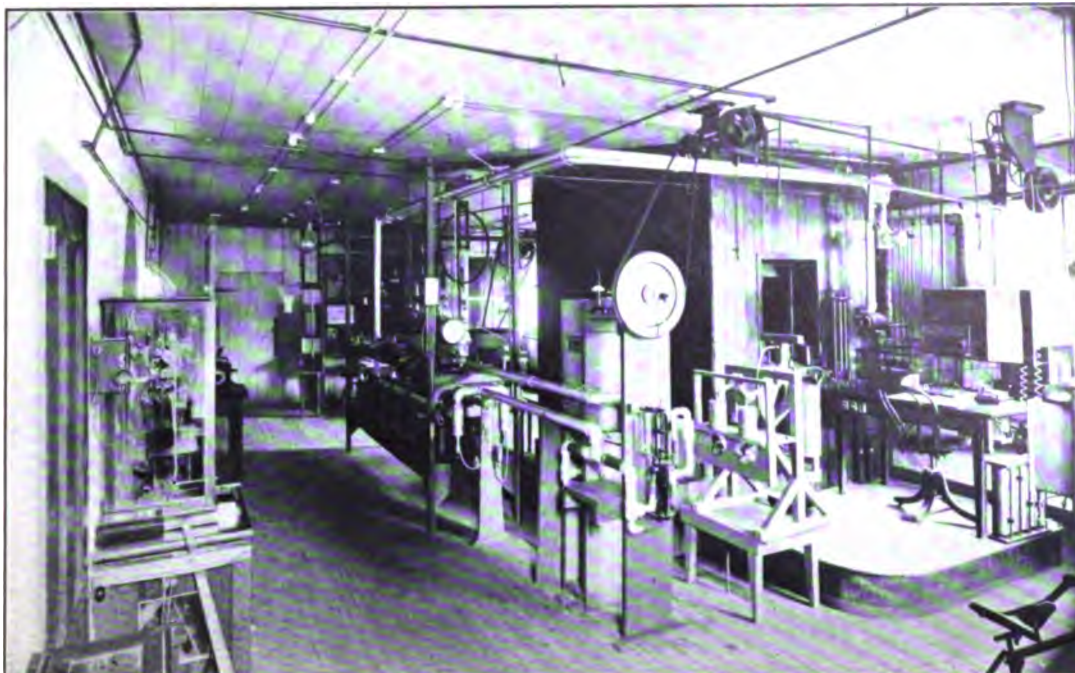


FIG. 17.—VIEW OF CALORIMETER ROOM, WESLEYAN UNIVERSITY

View shows the complete chamber closed, the observer's table, the old pump, and the closed circuit system

with myriads upon myriads of bacteria, each containing at a give instant the same *n* substances as are contained in A at the time T. How curious is all this to the chemist! That a mass of chemical substance, having a certain composition at a given time, should change and grow, and in that change and growth should suddenly reduplicate itself, and this over and over again, until this multiplication of the initial substance is extreme. Ah, well, this is assimilation, the one phenomenon beyond all others that has led man to believe in the existence of a transcendental "Life" governing matter. But re-examine the phenomenon described. This beef broth in which the bacteria are now swarming has changed profoundly from its original condition. There has been a large evolution of carbonic acid, and many new substances have appeared in it that are discoverable through chemical analysis. Evidently these swarms of bacteria are due to chemical interaction with the broth. In fact, this "assimilation" seems to resolve itself into this: That in the original bacterium A there were certain substances that can react with the medium to reproduce themselves up to the chemical destruction of the broth. This is a curious chemistry, and a new chemistry, but I fail to see anything in it *but* chemistry. Just why these plastic substances react with the medium to reproduce their identical substance nobody knows; but neither does anybody know, one whit more, why oxygen and hydrogen react together to produce a sub-

stance wholly different—water. Of course, chemistry knows more with every passing sun, but in the mean time it is satisfactory that this mysterious "assimilation," this multiplication of plastic substance, may be represented in the form of an equation. There are the plastic substance a, and the medium Q, and the products of the reaction R, and, hence, $a + Q = Xa + R$, where X is a number greater than 1. No "Life" figures in this equation; nothing superchemical—nothing hypermechanical; nor is there any visible reason why there should.

And as with "assimilation," so with the other functions of living matter—even with the mysterious phenomena such as contagion, immunity, the actions of anti-toxins, venoms, etc.; in no phenomenon of living matter is there to be found the necessity of postulating anything other than chemistry.

The search has proved unavailing; instead of living and lifeless matter there has been found—just matter; we have sought for "Life" and we have found "Law."

It is true that there have been here examined but the sparsest few of the known facts of natural knowledge. This has been done in order to make these few significant, and with the idea of saying in this place advisedly and plainly that all the related facts of contemporary science declare the same story, that there is no supernatural entity visible in the activities of living matter. Further, it is true that that which we know is as nothing to what

remains to be known; that science knows the secrets of "living" matter would be as preposterous a statement as man could make. There exist in the living body whole regions of activity of which science has no faintest glimpse, though we are sure that the secrets therein are chemical. Our knowledge is but a pinhole in the veil of our ignorance, but through this pinhole this much may be seen, that the complex mobile mass of matter undergoing chemical reaction that passes as a "living" being proceeds in substance, action, form, and motion as much under the laws of chemistry as any piece of zinc in a test-tube of sulphuric acid. We have seen the master workman at his work, but the face disclosed is Chemistry, not "Life."

We come, then, to the conclusion that every bodily action takes place through the operation of, and in accordance with, natural laws. If by "Life" is meant a transcendental entity that acts in place of these laws, or transects them, there is no evidence of its existence in living matter; the body is a mechanism through and through.

And yet, however unreasonable it may appear, and unnecessary and even absurd, this law-ridden living matter does not consist of matter alone. There are tangled up in it, somehow—associated with it—strange things called perceivings, thinkings, willings, feelings, and consciousness, things that are not matter at all. There are, thus, the two parts of us, the matter part of

us and the not-matter part of us. What is the relation between them? In this, of course, is asked the riddle of the world. The answers are not so many, and they are as old as thought.

It may safely be said that many, perhaps most, men of science—physiological chemists, biologists, and psychologists—are agreed upon one. "There is no 'Life' apparently necessary to, or visible in, the body; ∴ there *is* no 'Life.'" Upon this assumption they believe and they teach that all our feelings, thinkings, and willings, our very consciousness, are the products of the play of the physico-chemical processes in the brain. They believe that, were it possible to understand, completely understand, the nervous system of any man, it would be possible to account completely for his conduct; that man is an automaton, the most delicate mechanism in the world, composed of differentiated structures exquisitely sensitive to the play of physical and chemical forces, and wholly accounted for by them. They believe that mind is wholly a product of matter (collateral product, they call it), that consciousness simply "holds a candle" to our activities, and that the power of the will is illusory. In other words, there is no entity called "Life." This belief, which is, of course, very old, is now under a new name, *mechanism,* blowing about the world from corner to corner. But the men who are militant in preaching this creed are men of science, men whose philosophy is essentially an avocation; and con-

sequently the question arises as to how acceptable this creed is to modern philosophers, men whose sole business it is to study these high matters. It is safe to say that there is, today, in America, no teacher of pure philosophy of any prominence who is a mechanist, nor, indeed, any of the highest standing in Europe. This fact seems very significant, and it leads one to ask why men of science are so generally mechanists, and why philosophers are not?

The belief of the man of science, when carefully considered, seems to depend, not on reason, but on motive. The positive function of science is to arrange all phenomena in an orderly causative array; its ultimate ambition is to find for all the happenings of the universe one single vast equation, in which figures every past and every future event; the object of science is to destroy chaos. In dealing with matter the man of science finds himself most encouragingly successful in his efforts, and to such an extent that when confronted with mind he obtains an intense desire, in order to facilitate this great business of setting his house in order, to tag it on to matter *as a product*, thus bringing mind into the causal array of an exact mechanical system. This is the so-called "legitimate materialism of science."

But this materialism is really illegitimate. The philosophers have shown that it takes its rise in a pure assumption, that it is self-contradictory, that it is unimaginable, that it does not explain, and that it is the

result of a prejudice for an orderly universe at the expense of a significant one.

The great fundamental assumption of the mechanist lies apparently in placing in a logical sequence the two statements: There is no "Life" visible—There is no "Life"; the hyphen between them is actually a chasm of illogicality. That the body is a mechanism in which every muscle and gland and nerve functions through chemical law, and through nothing else, is a conviction that grows with every passing day; furthermore, if by "Life" is meant a spiritual entity that is interfering with these chemical processes, its existence may with reasonable safety be denied. But if by "Life" is meant a spiritual entity that abides within the body, and to a limited extent guides and directs its activities *without interfering with its energetics*, we cannot possibly deny its existence; our only means of detecting such an entity is through interference. That there may be in the body a resident entity that guides without interfering is not by any means contra-scientific. For example, it may be that the relation between the chemical nerve processes and the psychic processes is one of induction, crudely analogous, let us say, to electro-magnetic induction, and it is possible even today to draw a parallel between the two processes to a very persuasive degree. With the ever-growing establishment of the fact that biology is nothing but a branch of chemistry it is not forbidden us to imagine that ultimately in the far future

it may be possible through a new science, chemical-psychology, to correlate the chemical processes of nervous action with the psychic processes of a spiritual being enveloping them in such a way that it wlll appear, demonstrably, that "we, also, are His children."

1908.

V

THE BEGINNING OF THINGS

THERE is a picture, I think, that stands out prominently to all of us in the memories of our schoolday knowledge; it is one of the first pages of the geography, containing, with diagrams, a statement of the Nebular Hypothesis of Laplace. My own page, as I remember it, was much marked with little-boy thumbs and somewhat torn with use; it satisfied my childish demands for a consistent explanation of the beginning of things.

How the sun and the world and the planets and all their moons, millions of years ago, formed a vast sphere of fiery vapor extending out beyond the farthermost planet, Neptune itself; how this vast fiery gas slowly cooled and contracted, and in contracting parted with rings like the rings of Saturn—one ring after another, one for every planet; how among these rings there was the earth-moon ring; how like the others it broke and collected into a sphere; how this sphere formed a secondary ring, which, in its turn, broke and formed the moon; how the earth sphere, so formed, cooled from a fiery gas into a globular liquid which ultimately became covered

with a crust, upon which, when it became cool enough, the oceans collected; how in the oceans, by a miracle, God made living things, tiny living things, which evolved, after so many millions of years that it tired and frightened me to think of it, into grotesque forms that crept out upon the land, and after the longest time changed little by little into the little boy that was fingering the geographical page; it was all so satisfying, so explaining, that I forgot that it was called an hypothesis—a scientific guess—and accepted it for "really truly" true.

Now, what the little boy did, many very much "grown-ups" have also done. They have forgotten, virtually, that it was at best "a guess," and have founded upon it, and upon it alone, many important doctrines concerning the interior of the earth and its history. This is unfortunate, for the theory, impressive and satisfying as it has appeared, has always been open to certain grave objections, and these have become dangerously reinforced by others as science has brought new knowledge and new tools to bear upon the problem.

If, in accordance with the terms of the theory, the matter of the sun and the planets completely filled out, in the form of a fiery gaseous spheroid, the space within the orbit of Neptune, it turns out that the density of this gaseous matter could only have been about 1-240,000,000,000th of that of the air at the earth's surface. Does it not seem probable, then, that in matter so attenuated,

and under the intense temperature postulated, the contracting matter at its equator would separate out, not in the form of a ring, but as individual particles under velocities possibly so great that they would fly away, never to return? Does it not seem probable, too, that the outside matter of the sphere, in contact, as it would be, with the cold of outer space, would separate out in the form of solid particles long before these particles could collect into a sphere? Are we quite sure that the separated ring of gas demanded by the theory would, on breaking, promptly collect itself into a sphere? Such a happening is by no means so simple as has been assumed. A recent objection to the hypothesis, and one of heavy import, assures us that the rate of rotation of this supposed spheroid would have been wholly incapable of detaching these rings. It tells us, too, that the quantities of motion possessed by the different planets ought to have recognizedly legal relations with one another, while nobody has ever found such relations. It is a fact that Phobos, the inner moon of Mars, revolves three times as fast as Mars itself; yet it is incredible on the basis of the theory that a satellite should revolve faster than its associated planet. Nor, in this peculiarity, is Phobos unique, for the inner edge of the inner ring of Saturn revolves in half the time of the rotation of Saturn. Worst of all for the theory, the newly discovered ninth satellite of Saturn revolves in a direction *opposite* to that of Saturn and its inner satellites. Final-

ly, if this ring formation is what happens to a nebula, some at least of the nebulæ of the heavens ought to show these rings; they do not.

Therefore it has come about that the cherished "Nebular Hypothesis of Laplace" is no longer tenable; it is "an idol of the tribe"; it should be discarded. But discarded for what? Different attempts have been made to bolster up the hypothesis with modifying variants, but with conspicuous unsuccess. Professor Lockyer, Prof. G. H. Darwin, and others have endeavored to substitute for it a "meteoritic" hypothesis, but its terms are unacceptable and its working altogether too full of contingencies. We must turn for our new hypothesis to Prof. T. C. Chamberlin, of the University of Chicago, who with certain of his colleagues, and particularly with Dr. F. R. Moulton, to whom a very large share, indeed, of the credit is due, has evolved a theory of the beginning of things that seems to stand four-square to all the winds that blow. It also is a "Nebular Hypothesis," but in its demands and in its consequences it is so unlike that of Laplace that it has been called by a wholly new name—the Planetesimal Hypothesis.

The nebulæ of the heavens may be divided, in accordance with their spectra, into two great classes, the one possessed of bright-line spectra and the other of a spectrum that is continuous. These bright-line spectra mean, supposedly, that the nebulæ showing them consist

of incandescent gases, and those gases are, apparently, hydrogen, helium, and a hypothetical element, unknown upon earth, and provisionally called nebulium. The metals and other substances with which we are familiar on earth are absent from such nebulæ, their forms do not seem to possess any significance, and they seem to promise nothing so far as the direct genesis of the earth is concerned.

But with the other class of nebulæ it is wholly different. The fact that they yield a continuous spectrum infers that the matter of which they are composed lies there at a relatively low temperature and in a liquid or solid condition—probably solid. The fact that such nebulæ are enormously spread out, that they apparently intercept but little light, and that they seem to have but little attractive power, leads to the inference that this solid matter exists in a finely divided condition. Their forms are profoundly significant. Out of the 120,000 nebulæ which already are known to exist in the visible sky, there is one form among them that dominates every other—and that form is the spiral. To such an extent is this true that it is apparent that this spiral form "represents some prevalent process in celestial dynamics," and this process is, in accordance with Chamberlin's conception, with each one of them, the creation of a solar system, sun, planets, and attendant moons—that each one of these nebulæ is a solar system *in statu nascendi.*

FIG. 18.—A SPIRAL NEBULA IN URSA MAJOR

Showing a large dominant central mass, with symmetrical arms, well coiled, possibly somewhat advanced in evolution

In order to grasp the argument which makes this conclusion reasonable, it will be well for the reader to examine attentively the beautiful photographs of these wisps of light as they actually appear in the heavens.

Notice how obvious is the spiral form (Fig. 18); notice that this form is due in the main to two dominant arms that develop from the nucleus on opposite sides, and that then curve concentrically away; notice that on these arms, or near them, are knots or sub-nuclei; and notice, finally, that the whole system seems to be enveloped in a web of nebulous, finely divided material. The contention of the hypothesis is that the central nucleus represents the sun of a future solar system, that the knots upon the arms of the spirals represent the nuclei of young and ungrown planets, and that the nebulous material enveloping the mass represents scattered and finely divided matter from which these young planets are growing by accretion; the theory assumes that our own solar system was once a nebula of this prevailing type.

In order to develop the theory persuasively it is as well to begin by saying "Let us suppose." Let us suppose that our little system was once a star which we shall call our ancestral sun. Of the previous history of this star present-day knowledge offers no reasonable indication. It certainly had a previous history, possibly of former families of planets; of this we know nothing; it is just a star. Let us suppose next that into the

neighborhood of this star, and not the very near neighborhood, there came another star. This is by no means an unlikely contingency. There are probably at least 100,000,000 stars in our galaxy, to say nothing of the vast indeterminate number of those that are extinct and dark and now invisible. These stars move in all directions, with very varied velocities, and the contingency of an occasional close approach of one star to another is altogether likely to be realized in fact. With this approach certain events would apparently of necessity happen. Our sun, as it is to-day, is possessed of a prodigious store of explosive elasticity. This is seen in the enormous tongues of fiery matter, visible by special means, which day after day the sun shoots out into space for thousands of miles and with velocities as high as 300 miles a second. This explosive elasticity is restrained only by the equally enormous power of the sun's gravity. But with the approach of another star the gravity which restrains this enormous elasticity would be reduced along the line of attraction between the two bodies, the pressure crosswise to this line of relief would be increased, and, granting, as we say, only a very moderate approach of the invading star, it seems a certain deduction from celestial mechanics that out from our ancestral sun, and from opposite sides of it, there would fly two great protuberant arms of matter, which, owing to the attraction of the passing star, would be twisted into spirals (Fig. 19). We can easily see, as our

ancestral sun with its visiting sun swung about each other in their transient approach, that secondary arms might be formed, that the outburst would be profoundly irregular and pulsatory with the formation of condensations in the arms, and that there would be a scattering of a large amount of ejected matter in the form of a nebulous envelope. We can see that, owing to the inequalities of the projecting force, those lumps in the arms would be rotatory in motion, vortices of matter, and attended presumably by subordinate vortices, and, finally, we can see that this far-sent solar matter in the utter cold of outer space would sooner or later, and probably sooner, be congealed into solid lumps and particles, which would yield to the observer a continuous spectrum. This description of the extremely probable result of the invasion of one star into the territory of another pictures equally well the nebulæ of the sky as they actually exist in their prevailing habit. The theory assumes that the nebula from which we suppose our sun and planets to have originated arose as the result of a catastrophe to an ancestral sun. This catastrophe, while it seems prodigious, needs, relatively to the sun's mass and energy, to have been only very mild, for the amount of matter contained in our planets and their satellites taken all together does not comprise more than one seven-hundredth of the mass of the whole system.

Understanding, then, that our nebula arose through

a mere incident in the abysm of time—the approach of a foreign star to our ancestral sun—with the departure of this star our new-formed nebula was left to its own resources, left to reorganize itself from its disrupted fragments. It is in this reorganization that we see appearing the planets of which our earth was one. The large masses projected by the explosion, the knots or nuclei, lay enveloped by prodigious, incalculable numbers of smaller fragments—the planetesimals—but large lumps and small fragments together must have revolved individually about the exploded sun as a common center, and revolved, it is important to add, in orbits that were highly elliptical. This we must believe, unless the pull of the foreign star exactly equaled the propulsive force of the sun, which it would be absurd to imagine. This is borne out by the pictures of the nebulæ of this type; they are elliptical in form.

From such a condition of things certain results would seem of necessity to flow through the application of the principles of celestial mechanics. First, in accordance with the relative attractions of the moving masses, the orbits would shift and would interfere. Next, because of these interferences, collisions would follow and the larger lumps would grow by accretion at the expense of the smaller ones. But with every increase in growth the capacity for growth would be augmented, and so it results that through the lapse of time, and the reader may have for this process as much time as he

chooses to demand, it may be predicted that the larger lumps would capture by collision the infinite swarm of smaller fragments, and, immensely grown through this accretion, would remain alone to revolve about the central mass—the planetary nuclei would become planets.

Notice that unlike the Laplacian hypothesis, our theory provides that the planets were all formed at the same time, that they are all of the same age; notice that, owing to the catastrophic character of their production, they may be of any irregularity of relative size, as they are; that, owing to the fact that the lighter matter of the sun's surface would be projected first and farthest, we should expect the outermost planets to have a specific gravity less than the innermost, which is in absolute accordance with the facts; that while these masses projected from the ancestral sun would probably share the direction of its rotation, this direction might readily be altered by several factors, and that, therefore, what is in accordance with the Laplacian hypothesis the wholly anomalous rotation of some of the satellites would herein find a reasonable explanation; notice that since the nuclei of the satellites were formed independently of the planets, their rates of rotation need have no legal relations with the rates of their associated planets, that, to place it concretely, it makes no difference to the validity of the theory whether or not Phobos goes faster than Mars; and most importantly of all, notice that the momentum of the outer parts of the nebula pro-

duced must be very high compared with the inner mass, and that in this respect the theory meets at once the facts of our solar system and the gravest objection that has been advanced to the hypothesis of Laplace. It seems to follow as well, from the application of these same laws of mechanics, that the orbits of these new-formed planets would gradually change from the elliptical condition to one that approached circularity, and that the planets would finally space themselves out into positions such as they occupy to-day. Fig. 20.

Let us then imagine the beginning of our world not as an expanded molten mass that continuously cooled and contracted to the present day, but, on the contrary, as a small lump of cold and solid fragments that, moving about in accordance with its attractions, continuously fed upon its surrounding assemblage of smaller fry, and thus grew to its present size. About the young earth so engaged it is possible to read, on the basis of the hypothesis, something of its early history.

It could, we are persuaded, at the beginning of its career have had no atmosphere. The gravity of so small a body, let us say one-twentieth of its present mass, could not possibly have been of a magnitude adequate to hold the gaseous molecules of the enveloping cloud, or even, in fact, the dust and smaller fragments. But as the mass of the tiny earth grew by the accession of larger pieces, its attractive power would also grow, and finally there must have come a time when it

FIG. 19.—A BRILLIANT NEBULA IN CANES VENATICI

A noticeable feature is the comet-like streamers of some of the denser portions. They seem to imply an active rotation. The secondary nucleus at the extremity of the lower arm may possibly be interpreted as the disturbing star

could catch and hold the gaseous molecules through which it passed. The kinds of gases and the order in which they would be caught are important for what we have still to consider. The theory states, and on mathematical and physical grounds of what may be taken for perfect certainty, that the growing earth would obtain its gases in the following order: carbon dioxide, oxygen, nitrogen, and water-vapor. Considering, then the free gases caught by the growing earth, there must have been surrounding it and blanketing it an atmosphere at first essentially one of carbon dioxide diluted with the gradual accumulation of nitrogen, oxygen, and, finally, with water-vapor.

But the gases caught by the growing earth were not the only gases it possessed. While it was atmosphereless, it nevertheless had gases hidden safely away in the very substance of the meteoritic fragments that comprised it—gases that were *occluded,* as the chemical phrase goes. We know that the igneous rocks of the world to-day contain on the average several times their volume of occluded gas, and we know, too, that meteorites falling out of the almost perfect vacuum of space also contain these occluded gases. The occluded gases we may ascribe to the young earth on the basis of meteoritic analyses and of analyses of the earth's rocks are hydrogen, carbon dioxide, carbon monoxide, marsh gas, and nitrogen. These gases would remain hidden therein until forced out by heat.

This heat, it is deemed, was furnished to some extent by the pelting action of the colliding fragments, but most of all by the immense compressive forces of the earth's own gravity developing as it grew ever larger and larger, and culminating finally in an era of vulcanism. Under the expelling forces of that heat these occluded gases were driven from the rocks to add themselves to the primal atmosphere. This atmosphere, then, both from external and internal sources, was in very large measure carbon dioxide diluted little by little with oxygen, nitrogen, and, finally, with water-vapor. This water-vapor, when the earth was large enough to hold it, doubtless condensed on the barren surface in puddles, puddles which grew ever greater in volume and heavier in weight, until they had made for themselves the depressions in the plastic earth that now form the bed of ocean, and had washed out the soluble compounds of the earth's crust.

Concerning this era of vulcanism that drove the occluded gases of the rocks into the atmosphere, we are not to imagine, as with the Laplacian hypothesis, that it ever made of the earth an intensely heated body. We believe, rather, that of the cold rock fragments that comprised the original nucleus, certain mineral constituents melted while others did not; that these melted constituents forced themselves up, in the form of veins and tongues of molten matter, through the superincumbent rock, until some of it, arriving at the surface, overran

it in the form of lava-flows or in the form of explosive outbursts from blow-holes, such, for example, it may be, as we now see in the circular pits of the frozen moon. These lava-flows from the interior, mixed with the colliding fragments of the surrounding envelope, formed, probably, the Archean complex, the earliest rocks that we know, the entrance of recorded history, and the end of the beginning of things.

But some time during this eventful pre-history life arose. When? and where? and how?

That vast multitudes of plants and animals existing to-day have resulted from simpler forms, and these from still simpler, and these again from simpler still, down and down to some ancient simplest types, needs no argument for the cultured reader of the present day. This is organic evolution, and while men are desperately disputatious over the mechanism of this evolution, there is virtually no quarrel as to its probability as a fact. Organic evolution, if it teaches any one thing, teaches this: That there was a time in the world when of living matter there was none; that there was a time after that when living matter *was*—ever to continue to this present day; and that at some period, some instant, it may be, between the time when the geologist knows that living matter was *not* and that at which the paleontologist knows that living matter *was*, living matter *began*. Fig. 21.

Of course it has been suggested that the source and

origin of living matter was extra-terrestrial, that it was borne to the earth from another planet or on some flying meteorite, but the suggestion is without validity or probability. Particularly is this true on the basis of our theory, for in accordance with it *all the planets were formed at the same time.* As for meteorites, there is nothing in them to suggest an association with living matter. Meteorites consist of mineral bodies in the form of sharp fragments which show no signs of weathering due to the air and water that would be necessary for the existence of living matter. While it is true that they contain hydro-carbons, these hydro-carbons are readily assignable to an inorganic origin; and among the gases condensed in them there is neither free oxygen nor water-vapor.

It may be assumed, then, that living matter began on the earth, but as to just when it began, and in what form it began, organic evolution is silent, for on tracing it back into the remotest past, living matter vanishes from the records in the form of crustaceans and other organisms far too high up in the animal scale to give even a hint as to the nature of their origin, unless it be, indeed, that life, when it vanishes from the records, vanishes in the sea.

But the inorganic evolution that we have been considering has this, at least, to say: that since the earth from the time of its adolescence, so to speak, probably never at any time was too hot to render it unfit as an

FIG. 20.—THE SPIRAL NEBULA H. V. I. CETI

The nebula presents itself obliquely to our vision, thus revealing its disk-like form

abode for living beings, the origin of life upon it may be placed millions upon millions of years back of the time during which even the most daring speculator, on the basis of the old "cooling-globe hypothesis," has ventured to place it.

As to where it began, organic evolution tells us that when life vanishes from the records it vanishes in the sea. The inorganic evolution of our paper provides this primal sea in the formation of puddles growing ever greater in volume and leaching out the soluble constituents of the earliest rocks. The composition of these dissolved compounds is significant. The elements contained in sea-water are sodium, calcium, magnesium, potassium, chlorine, sulphur, carbon, hydrogen, oxygen, and iron. The composition of the air is nitrogen, oxygen, and carbon. *The elements contained in living matter are these identical things.* In the heavy carbonated air above and in the solvent water on the land beneath there lay in mobile contiguity the essential elements of living matter. Ages upon ages afterward, after the drama of evolution had unrolled through three-quarters of its course to the present time, far away up in the pre-Cambrian period, these inorganic elements appear combined in living beings, strong-knit and full-armed in defense of the life they possessed. How did it happen? How did these simple molecules of contiguous substances evolve into the multi-myriad complexities of living matter?

Before taking up this question I ought to emphasize the significance and the importance of the contiguity of these non-living substances in their relation to the living matter that was to arise from them.

Sea-water and air comprise the substance of man; but there is more than this to it; there is a relation between sea-water and living matter in the actual relative proportions of the elements that comprise each. For the elucidation of these important relations the world is indebted to Prof. A. B. Macallum, of the University of Toronto. The relative proportions of the constituents of the living body are most diverse in different parts of it, but suppose we compare with Professor Macallum the composition of the inorganic constituents of the blood-plasma with the composition of sea-water.

	Sodium	Calcium	Potassium	Magnesium
Sea-water	100	3.84	3.66	11.99
Serum of the dog	100	2.52	6.86	0.81
Serum of the mammal	100	2.58	6.69	0.8

After a surprised glance at this column, the reader is likely to confess that the relative proportions of the elements sodium, potassium, and calcium in the plasma of the dog and, in general, the mammal, are certainly very like those that obtain in the ocean-water of today. There is, however, a notable lack of similarity of proportion in the case of magnesium, for while in sea-water the proportion of magnesium to sodium is 11.99 to 100,

in the blood-plasma there is of magnesium but the barest trace. It is this very difference of proportion in the case of magnesium that leads to an interesting conclusion. The fact is that there is good reason to believe that the percentage composition of sea-water is by no means constant, that in different epochs of the past it has varied widely. Consider, for example, this magnesium. It is a fact of every-day chemistry that superheated water converts the chloride of magnesium into insoluble magnesia. The consequence of this little fact is that, as the ocean first formed, the quantity dissolved therein must have been exceedingly small. But as time went on and the ocean cooled, whatever of magnesium the water dissolved, or obtained through river discharge, it must have retained, for there is for it, unlike calcium, no removing agency. Consequently, when paleochemistry teaches us that there must have been practically no magnesium in the early ocean, and there must be, as there is, much magnesium in the present ocean, and when, related to this, there is discovered in the organic constituents of our blood a practical identity with sea-water with the exception of this magnesium which is almost missing, the conclusion seems almost inevitable that we have actually in our veins, fixed by heredity, the water of that early pre-Cambrian ocean in which the remote ancestors of man first assumed a closed circulatory system.

But this is not all. The inorganic constituents of the

solid tissues of our bodies, the ash of muscle, and such like, vary widely from the constituents of the liquid blood-plasma that we have been considering. Yet these too have their relations. One remarkable characteristic of living tissue is the great preponderance of its potassium content over its sodium. Now, there is a great deal of evidence going to show that in the earliest sea there existed also this potassium preponderance. An analysis of the earliest rocks shows this high potassium content, and analyses of the fresh-water lakes in contact with these earliest rocks show this same thing; besides, on the basis of our theory, the earliest waters probably consisted of just such fresh-water lakes. The conclusion is forced upon us that the ash of our bodily tissue registers the composition of that earliest of all seas, the primal ocean, which foregathered first with chemistry to the production of living matter. Strange, is it not? that we that quarrel so "about it and about"—about our lives and their origin—should bear with us in the fibers of our being the substance of our origin. We see, then, for there is no other way out of it, that not only did the air and water at the beginning of things contain in contiguity the elements of living matter, but that these elements did actually unite to form this living matter.

The *how* of their uniting is the eternal enigma. But what are we to think of these things? Are we to believe that far away, at the other end of time, a divine Chemist forcibly molded these constituents of sea-water into

those complicated molecules which possess the properties of living matter, and left them then to go their way through organic evolution? Or are we to believe that the properties inherent in these constituents brought them together in a wholly natural way? Or, finally, are we to believe that these constituents gradually folded themselves into living matter absolutely in accordance with chemical laws and properties, but that, nevertheless, there was a guiding action upon them to obtain this living matter without interference with those laws?

Between the first and second hypotheses the man of science cannot hesitate. He cannot believe that there was actually a break between the inorganic and the organic evolutions bridged over by the direct action of the finger of God. He must believe that there has been no break whatever—that waving palm-trees and toddling children and wave-beaten rocks are alike the present natural outcome of an absolute sequence of cause and effect passing back to the blazing star that formed the elements that comprise them. He must believe this because he believes in the Law of Continuity—the Law of Laws.

But between the second and the third hypotheses, what shall he say? Is this sequence that led to the creation of man self-guided, or guided without interference?

If it is self-guided, man ought, himself, to be able to create living out of non-living matter. Why not? If

Life arose from the chemical predisposition of certain inorganic salts and gases, then by carefully bringing together these salts and gases under suitable conditions he ought to be able to observe the manufacture of living matter in an Erlenmeyer flask. But this is just what man has not been able to do, or, at any rate, to prove he can do, and this leads us then to ask whether Nature in her vast laboratory could have succeeded better *without* intelligence.

Nature did succeed, there is no doubt about that, and succeeded through the normal operation of natural laws; but was it blindly, as in the fall of dice, or were not the dice loaded?

Concerning the first supposition that inorganic sea-water and air through blindly acting chemical laws evolved into substances of such transcendent complexity as living matter, all that can be said of it is that it seems one chance against all arithmetic; in other words, it is incredible.

On the other hand, the supposition that there was a guiding Intelligence working the synthesis of living matter without interfering either with its chemistry or its energetics does not seem to be out of consonance with contemporary knowledge; it seems, indeed, to be the one reasonable, believable, and uplifting theory of the origin of life.

But the interesting Planetesimal Hypothesis that has given rise to these reflections on the beginning of Life

is quite independent of them. It is a hypothesis that squares in a marvelous way with the related facts of contemporary knowledge, physical, chemical, and mathematical, and it is a matter of surprise that it is not better known and appreciated among men of thought. It is true that it does not explain inclusively every fact—that for example, it does not account for the peculiar luminance of nebulæ, nor, again, for the remarkable fact that meteorites, which, supposedly, are a type of matter out of which the materials of the young earth were compiled, do not possess any free oxygen or water-vapor. While Professor Chamberlin has evolved very ingenious hypotheses to account for these weaknesses, it seems probable that the theory will be able to account for them with perfect naturalness only on the basis of knowledge yet to be born, and this knowledge seems not unlikely to be an immense process of elemental synthesis and disintegration which is now foreshadowed by the work of Sir William Ramsay on the radium emanation.

But however this may be, the distinguished authors of this great hypothesis are to be congratulated upon giving to the world one of the most dramatic and consistent pictures of its genesis that have ever been evolved from the mind of man.

The beautiful photographs that illustrate this article appear through the courtesy of the Lick Observatory. They are the present outcome of a long and serious struggle on the part of the observatory to conquer the

mechanical difficulties connected with the reproduction of these delicate celestial photographs. The photographs, for the most part, were taken by the late Professor Keeler, of the Lick Observatory, and it is in large measure upon his work that the hypotheses of Chamberlin and Moulton rest.

1908.

VI

ON THE TREND OF CHEMICAL INVENTION

THERE is an office at Washington which some people call "the graveyard of dead hopes." It is a place to which men, the land over, after working under every circumstance of discouragement and failure, finally bring the results of their toil in order to obtain from the government "a temporary monopoly in their inventions." Often, much more often than not, the invention is immature, or it is premature, or its novelty is imaginary, or its utility is illusory, or its monopoly is fictitious, and the invention, together with the inventor's hopes, it is true, lies casketed in the Patent Office. But such is not always the case; the invention dies, but *invention* lives. The divine creative spirit in man ever drives him on, and out of the vast number of failures to increase the sum of the world's useful knowledge there results this much, at any rate, of accelerated progress that it always pales the achievement of each past generation into dull and empty insignificance.

One of the rarest and most valuable of the powers of man is "foresight," the ability to divine "the trend of things"—the trend of events, or, it may be, the trend

of knowledge; its exercise, too, forms one of the most interesting and most agreeable of preoccupations. But the Patent Office is a place in whose activities one may determine this "trend of things" not by this rare power of divination, but just by the merest observation. There, there lie actually *in statu nascendi* to-morrow's ways and the implements of to-morrow's civilization. It ought, therefore, to be profitable to examine into the activities of this office during, let us say, the last year, in order to discover therein what is interesting and significant.

Now, the Commissioner of Patents may be likened to a wine merchant. He has in his office the wine of human progress of every kind and quality—wine, one may say, produced from the fermentation of the facts of the world through the yeast of human effort. Sometimes the yeast is "wild" and sometimes the "must" is poor, and while it all lies there shining with its due measure of the sparkle of divine effort, it is but occasionally that one finds a wine whose bouquet is the result of a pure culture on the true fruit of knowledge. But it is this true, pure wine of discovery that is alone of lasting significance, and since it is for the most part to be found in those discoveries that are classed together as "chemical patents," I shall devote myself to them alone.

The first hurried examination of these patents yields at once a fact of the widest significance and interest. Here is a patent by Prof. Emil Fischer, of Berlin, on a

way of making mono-brombehenic acid; here is another by Prof. Wilhelm Ostwald, of Leipsic, on a way of converting the ammonia from coal-tar into nitric acid; here is a third by two young professors of University College, London, on a way of separating the impurities out of alcohol; and here is a fourth by Prof. Frederick Soddy, of Aberdeen, on a method of making an improved vacuum.

It is not the subject-matter of the patents that is of such interest; it is the fact that Fischer, the greatest living master-mind in organic chemistry; Ostwald, the giant among the physical chemists; Soddy, who with Ramsay discovered the degradation of radium into helium—and many other men of this type and standing, should be patenting their discoveries. A few years ago the university professor who "degraded his science to utilitarian ends" became a pariah among his fellows, and to take out a patent was, of all sins against the cloth, the one least forgivable. It was the duty of the man of science "to give his discoveries to the world." But things are now sweepingly different. Through the invasion of industry by science it has appeared that the scientific method is just as strictly applicable to useful as to "academic" knowledge; furthermore, it appears that the world is becoming increasingly convinced that ideas are *property*—just as truly property as homes and lands; and finally it appears that no man, however noble may be his desires, can "give his discoveries to

the world." This last clause may not be obvious, but to see it one has only to reflect that a discovery can go to the people only through the industries, and that the industries inevitably place upon it all that the "trade will bear."

These considerations taken together are reinforced by the necessity which is laid upon the university professor of associating with the newly wealthy cultured class upon a self-respecting basis, and have led him to feel that with entire propriety he may patent his discoveries. Not only so, but the patenting of a discovery actually forwards it. This appears in a conversation which the writer recently had with Professor Lippman, of Paris, the discoverer of the wonderful interference process of color photography. Said Professor Lippman, "In order to forward the development of this process I refused to patent the fundamental idea." The result was that nobody would touch it. "If you wish to give such a discovery to the world you should patent it." At any rate, whether it is to be deprecated or commended, the "trend" is there as an unmistakable fact, and every year we shall see an increasing number of patents taken out by the academicians of science.

Chemical patents deal with substance—how to make things cheaper, how to make them better, how to make imitations of things, substitutes for things, new things, and how to make artificially the natural substances of the animal, plant, or mineral.

ON THE TREND OF CHEMICAL INVENTION

First in obviousness among the patents are those which deal with the utilization of waste. Thus with fuel: Through the gradual depletion of the fuel resources ot the older countries and the conservation of our own through combinations of capital, the consequent rise in the price of fuel the world over has forced contemporary men to look for burnable material in what was the waste, of former days, in coal-dust. This coal-dust is mixed with some binding material in order that it may appear as little briquettes of various shapes and sizes—mixed, it may be, with tar; plaster of paris and chromatized gelatin; cement and tar; or linseed meal, sulphur, flour, glucose, and lime. In certain cases substances are added to increase its combustibility—substances such as manganese dioxide or niter. Not only coal-dust, but turf also appears in many patents. In order to turn the turf into fuel it is dried and mixed superficially with rosin for pressing, or, it may be, with naphthalene. Most of these patents are German, as is to be expected from a country in which fuel is so economically used; but some of them are American, and it is as clear as sunlight that tomorrow we shall see burning in our hearths the waste of former days. And just as our fuel will be artificial, so will be the walls of our homes. Artificial stone is the subject-matter of many a patent. For the most part it consists of cement mixed with asbestos, although, instead of this, sawdust and paraffin may be mixed with sand and a solution of magnesium chloride;

or again, it may be made out of the mineral magnesite, mixed with zinc oxide and magnesium chloride, or silicic acid.

Another phase of human effort strikingly apparent in present-day patents concerns the improvement of substance either by extracting from it and using in its stead its essential principles, or by removing from it its injurious constituents. Many examples appear, and particularly in foods. Thus with coffee: Many patents propose a coffee extract made for the most part by grinding the beans with volatile solvents and afterwards extracting the fatty and aromatic substances by water; others, again, are concerned with the removal of the noxious ingredients. One, for example, proposes a caffeineless coffee; while another has in mind the lessening of the tannic acid content by impregnating the coffee with potassium carbonate and sodium hydroxide; while still another, sad to say, is concerned solely with the improvement of the attractive qualities of the unroasted beans by treating them with oxides of nitrogen, whereby their odor and flavor are accentuated. But if caffeineless coffee is considered desirable, so is nicotineless tobacco, for several proposals are made to pass superheated steam through tobacco with the object of removing the injurious nicotine, which is subsequently condensed and is good, we are informed through another patent, for tanning hides. As with coffee and tobacco, so with beer. A certain interesting patent

originating in Russia proposes to make a beer equal to Münchener or Pilsener by determining the ingredients of the soft water of the malt-house. It seems that water rich in alkaline-earth carbonates dissolves certain resins in the gluten of the barley, and that these resins possess a bad and bitter taste. "Therefore," say the patentees, "why not make the waters used in beer-making identical in mineral content with the waters used in the beers to be imitated?" The results are declared to be satisfactory. Another interesting patent, English in origin, has to do with an imitation beer. It is proposed to flavor the carbonic-acid gas used in artifically carbonating the "beer" by passing it first through a warm cushion of hops. It is declared that by this means the smell of the hops, which is apparently deemed the essential constituent, may be transmitted to the "beer."

These are but trivial, though interesting, examples of a tendency which tomorrow will be an actual phase of our civilization. Ever more and more our foods, and, indeed, all the implements of our civilization, will be refined away of all unessential constituents and will be reduced to the pure active principles.

Inventors are like others of human kind; they flock to a newly discovered Klondike, and the original discoverer oftentimes finds his little mine surrounded, tunneled under, and completely enveloped by claims of a wider scope.

This is curiously instanced in the attempts which have

been made in recent years to produce nitrogenous material out of the nitrogen of the air; it is the most unimaginative fact in the world that men must either solve this problem or starve. One promising and, indeed, actually successful process for this purpose is that of Birkeland and Eyde, of Norway, who on a large scale are now causing the nitrogen and oxygen of the air to combine under the influence of flaming electric arcs. But these inventors, successful as they are, will need to look to their laurels. The patent reports are replete with alleged improvements on the method. One patent assures us that this same burning of nitrogen may be accomplished as well by simply heating the air to 1200° C. and then rapidly cooling it. Another accomplishes the same result by heating the air in a water-jacketed furnace to 2500° C. or 3000° C. Still another succeeds by subjecting the air to a maximum current of only 120 watts, but possessed of a minimum potential of 100,000 volts, the air being under a pressure of less than one atmosphere. This last patent is peculiarly interesting owing to the fact that it is issued to a company whose process was supposed to have been killed by the Birkeland method. It shows us how dangerous it is to celebrate the obsequies of any process prior to its actual decease. Another process for the fixation of nitrogen, which is today being used over Continental Europe and for which several factories are now being built in America, depends upon the production of calcium cyanamide

by pouring the nitrogen of the air over red-hot calcium carbide. But a recent patent improves this by mixing with the carbide 10 per cent. of calcium chloride, under the catalytic influence of which the nitrogen is much more easily absorbed. But a patent still later uses calcium fluoride instead of chloride. It is evident that the manufacturers of cyanamide will also need to look to their laurels. Perhaps the most interesting patent in this connection is one based upon a wholly novel method of converting atmospheric nitrogen into the fixed and useful form through the metal calcium which is now obtainable at a comparatively cheap rate by the electrolysis of the fused chloride. It is a well-known fact that this metal calcium readily unites with nitrogen to form calcium nitride, Ca_3N_2, but it is not so well known that this nitride will react with hydrogen to form calcium hydride, which in its turn will react with more nitrogen to form calcium nitride again and *ammonia*. The result is a process in which the calcium passing alternately through the condition of nitride and hydride is able to transform into the valuable ammonia indefinite quantities of hydrogen and atmospheric nitrogen. This process, too, lets us into a secret—the reason why so many recent patents have appeared dealing with methods of obtaining pure hydrogen from waste gases—gases such as blast-furnace gas. They obviously have in mind, partly at least, the manufacture of ammonia through calcium hydride. But this calcium hydride has a utility

wider still. It will react readily, almost violently, with water to produce free hydrogen and lime, and hence we are not surprised to find a patent dealing with calcium hydride as an ideal agent for aeronautics—for filling balloons. Another nitride, easily made by passing atmospheric nitrogen over hot magnesium, is readily capable, according to a contemporary patent, of conversion into cyanides. It is apparently only necessary to have a mixture of magnesium nitride, coke, and sodium carbonate in order to arrive at sodium cyanide, so useful in gold-mining. Still another patent interested in manufacturing products from air proceeds to make ammonia by passing the nitrogen from the air mixed with steam over hot turf. Altogether, we see that, in common with the initiators of all other processes and as typical of the course of invention, the original converters of atmospheric nitrogen are not unlikely to be drowned in the flood of new processes that take their origin from them—the invention dies, but *invention* lives.

The trend of an invention is always and ever toward the conservation of natural products to uses more valuable than those for which they were originally employed. For example: Next to air, perhaps the cheapest and most abundant gas in America is what is called natural gas—that gas, essentially methane, or marsh gas, which, arising from the earth, furnishes light and heat and power to so many of our people. It has been a vast pity in the past that this gas, so abundant and so ready

at hand, should be good only for burning. It ought, one thinks, to be possible of conversion into valuable substance. And, indeed, it is today partially so convertible. The methane of natural gas may to a slight extent be transformed with air into methyl alcohol, formaldehyde, or formic acid. Were it capable of complete conversion, a thousand cubic feet of gas would furnish at least 70 pounds of methyl alcohol, or 66 pounds of formaldehyde, or 101 pounds of formic acid. It is particularly interesting, therefore, to find certain contemporary patents ambitious of solving the problem. They are in origin, most of them, French. One states that a mixture of methane and nitrogen in excess is capable of transformation into ammonium cyanide. This cyanide, so formed, is in its turn easy of transformation into ammonium sulphate, the fertilizer, and into prussic acid. Another patent states that methane is convertible into methyl alcohol, formaldehyde, and formic acid by oxidation with hydrogen peroxide or ozone in the presence of ferrous sulphate. Still another makes chloroform from methane and chlorine in the presence of a large excess of nitrogen and under the influence of an arc lamp. It is extremely doubtful that these patents have solved the problem, but the trend of effort is perfectly apparent, and we may be certain that in some tomorrow some man will surely begin the process of converting the vast millions of cubic feet of natural gas, which, so far as chemical products are concerned, now go en-

tirely to waste, into valuable adjuncts of our civilization.

Oftentimes it happens that a substance whose properties are supposedly thoroughly understood assumes new properties through the application of a new process. Thus with graphite. Its utility through lead-pencils and stove-blacking suddenly, in recent patents, is supplemented by a supreme utility as a lubricant. Of course the fact that graphite has lubricating powers has been known and used for generations, but that it had a unique value in that respect it remained for Mr. E. G. Acheson to demonstrate through his process for the production of deflocculated graphite. The story of the way in which he was led to this discovery constitutes an interesting chapter in the history of invention. In 1901 Mr. Acheson, who had already done a great work for the world in the discovery and manufacture of the famous carborundum and, as well, of artificial graphite, became interested in the idea of manufacturing his graphite into crucibles. He discovered, first, that the clay which was used as a binding material for these crucibles the American manufacturers found it necessary to import from Germany, for the reason that the German clay was more plastic than the American. And he found next that a chemical analysis failed to account for the difference. Now, these German clays are what are called secondary clays—clays that have been transported from one place to another by the forces of nature,

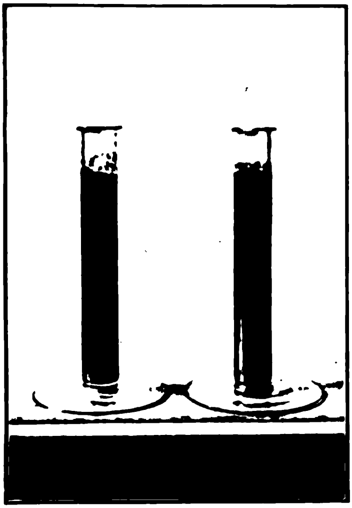


FIG. 22.—ONE TEST TUBE CONTAINS GRAPHITE AND WATER; THE OTHER GRAPHITE, WATER AND A LITTLE TANNIN

The photograph was taken immediately after the tubes had been shaken.

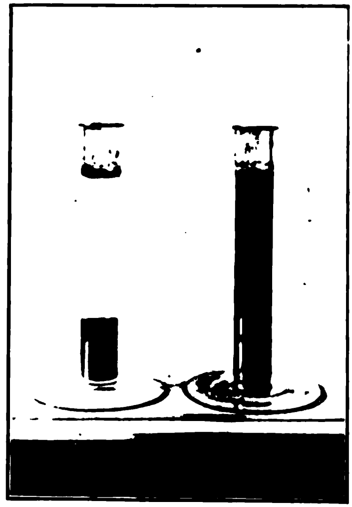


FIG. 23.—THE SAME TEST TUBES LEFT UNDISTURBED FOR FOUR MINUTES

The graphite has settled out of the tube which contains no tannin.

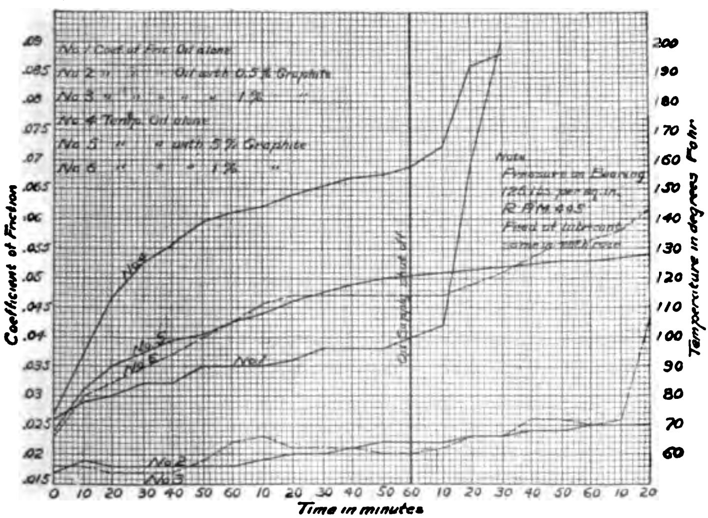


FIG. 24

Initial Friction Oil and 0.5 per cent. Graphite . . . . . 65 per cent. of oil alone
After 60 m. Friction " " " . . . . 55 " "
Friction of Oil increased . . . . 54 per cent.
Friction of Oil and Graphite increased . . . . 30 "
After lub. was shut off friction of oil increased . . . . . 125 per cent. in 30 min.
After lub. was shut off friction of oil and graphite increased . 14 " " 80 "

Spindle Oil was used in all tests.

and they owe this property of plasticity apparently to this transference. Why? "Well," said Mr. Acheson, "possibly the increased plasticity is due to the solution of vegetable matter through which the clays are dragged." And so he ground his clay in an extract of straw! The result of this daring inference and consequent experiment was astonishing; the clay assumed a condition of fine division, it remained suspended in the water, and it was *plastic*. As Mr. Acheson was acquainted with the interesting record of how the Egyptians compelled the "children of Israel" to forego straw in the making of bricks, and as he believed that the benefits of the straw were due not to the fibers, but to the water extract, he called his clay so treated "Egyptianized clay," and so it took its place in the market. It turned out subsequently that the active principle in this extract of straw was tannin. Now, in 1906 he discovered a process of producing a fine, pure, unctuous graphite, which he was desirous of using in oil as a superior lubricant. But he found that the graphite so suspended in oil quickly settled out of it, and that it was only by grinding his graphite in water containing a little of this same tannin that it would remain in a homogenous mixture. So treated, however, the graphite assumes a state of division so fine that its particles may almost be called molecular, and its suspension either in oil or in water is almost indefinite in duration. Deflocculated graphite, as this tannin-treated

substance is called, has a wholly remarkable value as a lubricant whether mixed with oil or with water. Through tests carefully carried out its remarkable power in that respect has been illustrated. Even when mixed with water to the extent of only 0.2 per cent. it has a good lubricating value, and with, also, the curious consequent effect that the water in which it lies does not rust the iron of the bearing. Figs. 22, 23, 24.

It sometimes happens that a substance may be the subject of contemporary patents and may even pass into current industrial use while still wholly new and practically unknown to chemical science. Such a substance is technically known as "Monox." It is apparently essentially silicon monoxide, and yet for such a substance the reader would look in vain through the dictionaries of chemistry. It is produced by stealing the oxygen away from silica by heating it in the form of glass-maker's sand in contact with coke in an electric furnace. Under these circumstances the "silicon monoxide" flies out from the veritable volcano-like effect of the furnace reaction in the form of a voluminous brown smoke—so voluminous that when simply shoveled into a box it weighs only about two and a half pounds per cubic foot. So formed, it constitutes an extremely fine, silky-feeling, light-brown, opaque powder, whose properties bid fair to make it a new industrial agent. Thus it becomes powerfully negatively electrostatically charged on the slightest provocation, and because of this it be-

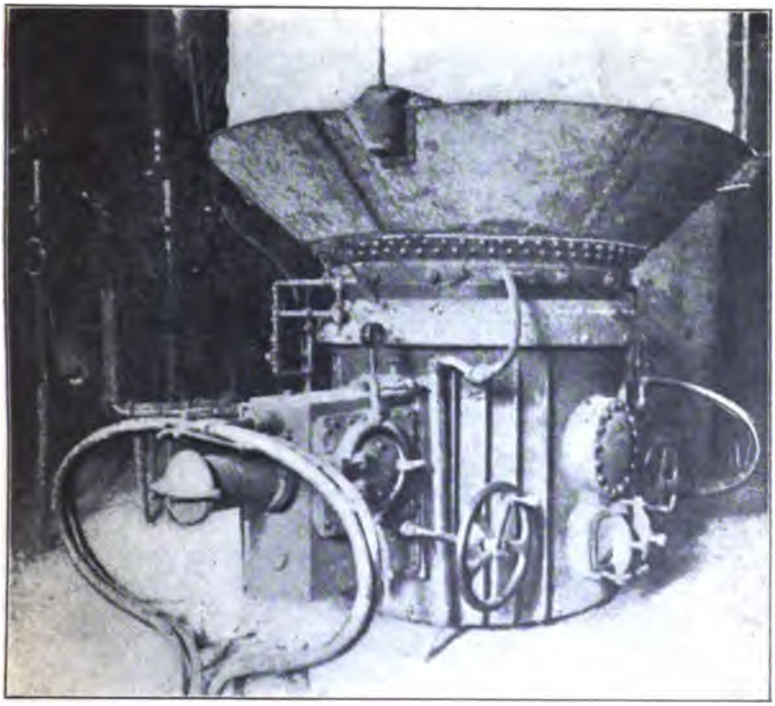


FIG. 25.—FURNACE FOR MAKING "MONOX".

comes possible to collect it upon a fabric in such a fashion that while it will permit a gas to pass through the fabric unimpeded, it will definitely stop all fine particles, from tobacco smoke to germs. As a screen for sterilizing air it seems, therefore, to have a broad field of application. Again, it has a remarkable power of absorbing gases, and, as well, it seems to be utilizable in ceramics, for since when it burns it burns into silica with the evolution of a considerable amount of heat, it prevents the phenomenon of auto-firing. Its main industrial function, however, lies in its utility as a paint, for its light, pleasant color, together with its chemical inertness and opacity, renders it a peculiarly valuable pigment for brick-work and for protecting iron-work from rusting. Fig. 25.

Now, substances such as "Egyptianized" clay, "deflocculated" graphite, and "Monox" are what are called "colloidal" substances, and they prompt me to a word or two on the colloidal condition as it exemplifies the trend of chemical invention. By colloidal substances is meant those forms of matter that exist in a non-crystalline state, that remain suspended in water, and that pass unimpeded through filters. If we could but calculate the waste that has resulted through the inability of men to deal with "slimes," and in general with the finely divided, non-settling substances of chemical processes, the total would be expressible only in millions of dollars of a horrifyingly large number. But in very

recent years, and mainly through the rapprochement between chemistry and physiology, means are rapidly being obtained of dominating them; in other words, some of the laws of their action having been observed, they may be governed in accordance with these laws. To illustrate: There exist contemporary patents based upon the curious fact that certain substances, when held in the form of a muddy suspension, will wander when placed under electrical influences. Thus, if into a copper vessel which is made the negative terminal of an electrical circuit there is placed a mixture of pure water and fine clay, and if into this mixture there is dipped a zinc rod constituting the positive terminal, on making the circuit the clay particles will migrate to the zinc rod and will build themselves up thereon into a hard, compact mass. This curious effect depends primarily upon the voltage of the current. The actual amount of current employed is practically insignificant. The industrial possibilities of this brilliant idea are numerous and valuable. For example: There exists in Germany a wide area of peat-bogs that heretofore have been of little use; this for the reason that the amount of fuel required to evaporate the water in the peat is almost as large as the amount of dry peat obtained. But the discovery of this new process of electric osmosis, as it is called, suddenly raises the value of these great peat-fields to a high potential. To obtain the dry peat it is only necessary to convey the peaty water to a metallic caldron

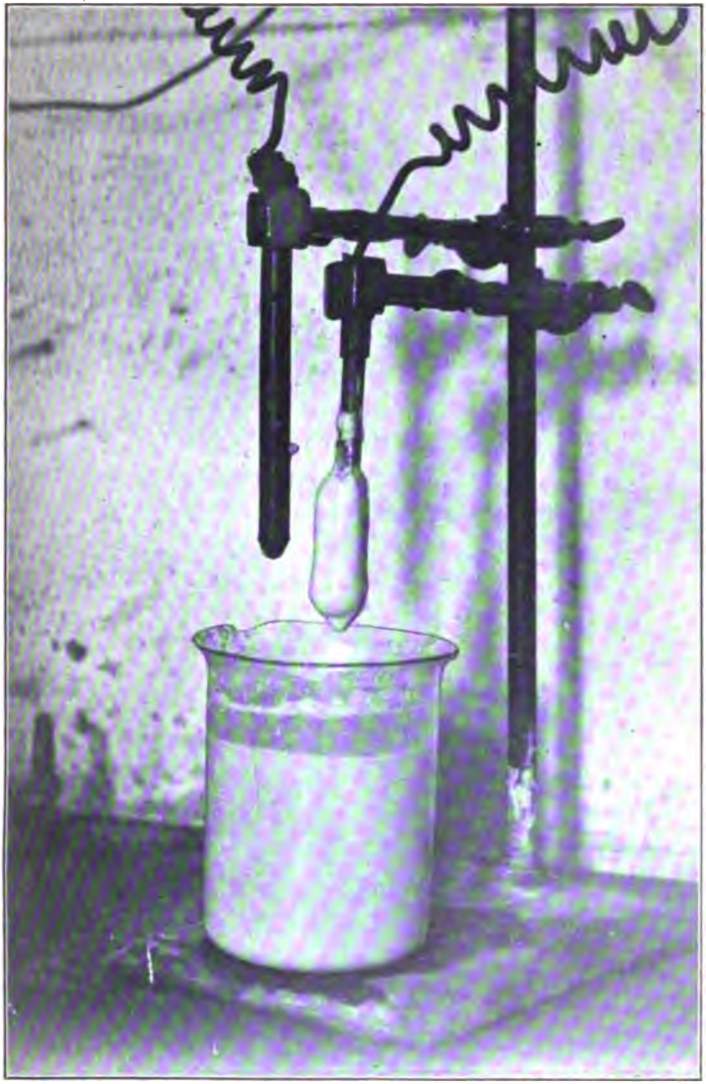


FIG. 26.—INDUSTRIAL APPLICATION OF ELECTRIC OSMOSIS

The experiment shows how when two terminals are dipped into a suspension of zinc clay the clay will collect on one terminal

connected with one pole of a dynamo and to insert into the water a metallic rod connected with the other terminal. Under these circumstances, the particles of peat rapidly migrate to the central rod, where they form a hard, caked mass which may be lifted out practically dry—and all this with the expenditure of an insignificant amount of energy. Recent patents by the aggressive experimenting industrial firms of Germany, such as Meister, Lucius, and Brüning of Höchst, foreshadow a wide general application of this entirely interesting phenomenon. Fig. 26.

Ever since the dawn of the age of iron men have desired to weld one metal with another—to weld, for example, iron and copper for the making of weapons and for the use of husbandry and building. Unable to accomplish this directly, they had to resort to the art of brazing, by which copper and iron might be joined together through a hard solder composed of brass and zinc. But such a joint was always imperfect, and sooner or later gave way to a severe stress. Through the advance of knowledge, several processes, mostly electrical, have been devised, but they are special processes requiring skill and complicated. It would seem almost incredible that men through all these ages should have overlooked a simple device by which this welding might be accomplished. According to Professor Simpson, of London—and the writer observed the actual demonstration of the method—in order to weld a bar of iron to a sheet of cop-

per it is only necessary to wrap the uncleaned copper closely about the bar, to bury the bar so wrapped in a crucible containing finely ground retort-carbon containing a little sugar water to make it binding, and finally to heat the crucible in a furnace for half an hour to a temperature somewhere between the melting-point of copper and iron. The result of this simple operation is a weld of extraordinary perfection and tenacity, tougher than either of the metals that constitute it. Figs. 27, 28, 29, 30.

There are certain industries that seek protection from the Patent Office as little as possible, and that depend for the security of their discoveries upon secrecy; their plants are fortresses sternly guarded from any espionage. Chief among such industries is that concerned with the manufacture of explosives. Still, they too must occasionally seek safety in the Patent Office, and hence certain significant facts appear. Contemporary patents tell us plainly that this industry is eagerly anxious to introduce into explosives substances that will lower the temperature in the gun-barrel, and so we find that they are using for this purpose substances such as derivatives of the cyanamide used for fertilizer, of urea, and of guanidine, the introduction of which, it is claimed, will not only lower the temperature within the gun-barrel, without diminishing the ballistic force of the explosive, but will at the same time diminish the amount of smoke. We find too a tendency to pass

FIG. 27. — HARD STEEL TEETH WELDED TO AN IRON WHEEL BY MEANS OF COPPER

FIG. 28. — MINGLED COPPER AND STEEL

FIG. 29. — THE SURFACE OF THIS MECHANISM IS IRON WELDED TO COPPER

FIG. 30.—MODEL GUN AND PROJECTILE COMPOSITE OF STEEL AND COPPER

away from the conventional guncotton and nitro-glycerin to other nitro derivatives of organic compounds, such as the toluenes, and chlorine derivatives, such as the chlor-hydrines. There is also a marked tendency to use in the manufacture of explosives substances hitherto wholly unknown in the industry—substances such as aluminium, sodium, calcium carbide, ferro-silicon, etc.

There are a few processes in chemical industry whose improvement notably affects, not one industry, but all. Typical of these are the processes of oxidation and reduction.

Most prominent among the oxidizing patents are those concerned with the making of the peculiarly active modification of oxygen known as ozone. Since ozone when it has accomplished its work reverts to pure oxygen, it constitutes, if it could be prepared cheaply, the ideal oxidizer. It is formed from the oxygen of the air under the influence of an electric discharge, and it is in the arrangement of the circumstances under which this discharge takes place that the patent specifications are chiefly concerned. One man would pass his oxygen through hollow electrodes with fine openings into the ozonizing chamber; another would employ an electrode consisting of sets of needles; and still another would discard electricity for ultra-violet light. At present almost the only industrial uses for ozone are the production of vanillin from oil of cloves, as it is practised at Niagara Falls, and for the large-scale purification of

water. But with the extraordinary activity of invention in this field we may easily foresee a rapid extension of the use of ozone in industry. So also with hydrogen peroxide, for the manufacture of which we may anticipate in the future a vast extension. The fact that after doing its work it reverts to nothing but water makes it, like ozone, almost ideal. Superimposed upon the manufacture of hydrogen peroxide there is the production of the metallic peroxides, which are utilizable in processes ranging from the restoration of oxygen to the air of submarine vessels to their oxidizing value as a constituent of dentifrices. Finally there are the persulphates, percarbonates, and perborates, for the commercial production of which invention is remarkably active. As for reducing agents, the new powerful sodium hydrosulphite, which, as the result of many years' work, is now appearing from the great German "Badische" firm, will percolate through numerous processes.

Altogether, outside of the significance which is integral to the subject-matter of each patent, there is the wide-sweeping significance of the application of pure science to industrial ends, and, therethrough, the entrance of efficiency into factory practice. That the one follows upon the heels of the other is best exemplified by reference to Germany. Fully three-quarters of all the patents of real chemical interest are German in origin, and it is, of course, in Germany that we find efficiency in factory practice the *sine qua non* to its

operation. The American manufacturer who does not realize in a practical way that he can no longer rely for success upon trade combinations, upon cheap raw material, upon an ultra-protective tariff, upon negligent government supervision, and so on and so on, but that henceforward essentially he must stand or fall by the degree of efficiency he has obtained in his factory, will bitterly rue his ignorance and his negligence. What the writer believes to be a sane, practical method of solving the problem of waste and of progress he has developed into a scheme of temporary industrial fellowships, which he has outlined in another place. But whether the manufacturer takes his problems into the university, or the university into the factory, in order to survive the swift-coming era of competitive stress, he must become efficient, not only in his office, but in his factory.

VII

CAMPHOR: AN INDUSTRY REVOLUTIONIZED

THAT the processes of civilization are transforming the world with a velocity which is undergoing a continuous acceleration everybody, as a matter of intellectual acknowledgment, would be willing to admit, but the meteoric character of the velocity of this change is perhaps almost only adequately realized by those representatives of the great industrial corporations who are incidentally acting as the agents of Providence in its accomplishment. North, east, south, and west, pampas, savannahs, sierras, wind-swept hilltops and breathless jungles, all the imagined inaccessible places of romance and mystery, are yielding to the engineer, the manufacturer, and the industrial agent, and yielding, too, at such a rate that we are assured that even within the knowledge of our great-grandchildren this diverse and parti-colored world will have assumed the dull-gray tones of a universally static condition, a condition in which there will be probably, in so far as the conveniences and ideals of our civilization are concerned, but little essential difference between Canton, Ohio, and Canton, China. This coming gray monotony of life is desirable,

is regrettable, is inevitable, though we are sure that it, too, will yield ultimately and in its turn to vari-colored segregations of life and manners in new and beautiful forms and in a new and better world.

Meanwhile, with the rapid passing away of the older or different civilizations under the aggressive dominance of our own, there is passing away much, both of forms of knowledge and forms of life, that is of the highest potential value, and that never can be recalled.

There passes into some one little country of the immemorial East some one rather tawdry form of knowledge of our rather vulgar civilization, and forthwith there vanishes from that country some other form of knowledge, its own, the painful product of toilsome centuries of innumerable men—valuable to them and potentially valuable to us did we know enough to use it; it may be a dye, a perfume, a medicine, an edible dish, a thought, or a code of conduct, but it is gone absolutely and irrecoverably. As with forms of knowledge, so with forms of life; there is never a month passes but some species disappears which it has taken, not man but nature, not centuries but eons, to accomplish; and with all its place in the balance of life, with all its possibilities of usefulness, it is gone into eternal oblivion. Not merely the far future but the immediate present cries out for the conservation of such.

To speak plainly and emphatically and within the circle of interest of a materialistic age, I say that if there

are enormous pecuniary and material results to be obtained through forcing the products of our civilization upon foreign peoples (and about this there can be literally no question), there is just as much material gain to be obtained through taking over from those foreign peoples their own disappearing forms of knowledge and forms of life and converting them to the needs and uses of our own civilization.

In order to precipitate this idea into a concrete form I might cite many instances of the profit of introducing Eastern knowledge into Western life, or Eastern life into Western knowledge, but it would take many a book to chronicle such. Let us rather take some one example—and as one happens to fall pat within contemporary interest, I shall take the subject of *camphor*. The pure, white, waxen camphor is to be found in every drug-store of every village of civilized man; every human being knows it when he sees it and smells it. It has been employed for countless generations as a fever specific, as an agent of purification, as an insecticide, etc.; and in later times in immense quantities in the manufacture of celluloid, in the preparation of high explosives, and in many other ways which have just arrived. But always it has come to us out of the East, from Japan and Formosa and China, but mostly from Formosa. There it exists locked up in the cells of a certain tree, the *Laurus camphora*, which, growing to a height of forty to sixty feet, covers with the shade of

FIG. 31.—A CAMPHOR-TREE

its beautiful waxen leaves many thousands of acres of these semi-tropical lands. The traditional method of the extraction of camphor from the camphor-tree illustrates the art of manufacture under its most savage and primitive conditions (Fig. 31). A crude furnace temporarily constructed in the heart of the camphor forest, a rudely fashioned box to contain the chips and fragments of a neighboring camphor-tree, the hollow trunk of a tree to convey the steam and volatilized camphor from the chips, and an earthenware receptacle in which the camphor is condensed express the practice of the simple art of these people and their idea of the process of distillation by steam. Only trees at least fifty years old were felled for extraction, and only the wood of the tree was employed. How wasteful and mistaken was this traditional process will quickly be seen, but upon it, we must understand, for centuries we have been dependent.

The Russo-Japanese War, however, with its vivifying influence upon the people of Japan, as well as the coercion of the resulting vast public debt, turned the attention of the Japanese to this important product, and thereupon quickly followed certain results. First, the production of camphor was constituted a government monopoly, employing a bureau of its own, and fixing absolutely the selling prices on a continuously rising scale; for example, from 2.61 M. per kilo in the year 1903 up to 4 M. per kilo in 1907. They then proceeded to stimulate the camphor industry by increasing the

buying price from the producers. Next, as the camphor-trees in Formosa were practically exhausted in the settled districts, they evolved and set in motion a scheme of reforestation on a huge scale; in 1906, 346,000 trees were planted, in 1907, 1,300,000, in 1908, 4,830,000, and last year, 5,060,184 trees were placed in the ground. Finally, in order to supply the present market, very expensive expeditions were organized against the savages in the unsettled portions of Formosa, where camphor-trees abound. All this, one would think, would insure the validity of the monopoly desired, for the attempt seemed to be marked by all the intelligent foresight and the logical acumen that adorn successful monopolistic control. But the attempt to create a permanent monopoly in any natural product is a challenge to the world at large, and the failure of the Japanese government to establish it might fairly have been predicted. I shall use the "reasons why" for this failure not only for their general significance, but, as well, to exploit the interesting question of camphor itself.

First, it should be understood that camphor is a definite, individual chemical substance, and that while this fact would not interest the denizens of the forests of Formosa, it does most surely interest the denizens of chemical laboratories. For every individual substance has a story to tell to the chemist—a story just four chapters long.

Chapter I—How it may be isolated and analyzed;

Chapter II—What is its constitution, or how its atoms are related to one another in its molecule; Chapter III—How it may be synthesized—*i. e.*, made in the laboratories out of other substances and by methods with which the plant or animal has nothing to do; and Chapter IV—How it may be made on the large scale—*i. e.*, manufactured in such a fashion as to compete with the natural product. With the termination of the fourth chapter the covers are closed. But the decipherment of camphor has been one of the most difficult undertakings of chemical science. From 1785 on it has employed the skilled labors of generations of chemists. Its constitution was fought out through the claims of thirty warring formulas. In 1903, however, and, through the irony of fate, just when the Japanese had piously begun to raise the price of natural camphor, its constitution was established beyond cavil by the triumphant synthesis of the artificial product under the hands of Komppa. In view of the enormous difficulties of the subject, it is a reasonable statement that this making of a camphor in the laboratory identical with the camphor of the camphor-tree constitutes one of the greatest contemporary triumphs of mind over matter. Komppa's synthesis was purely academic and wholly uncommercial, but it sealed the fate of the Japanese monopoly, as might readily have been divined by so astute a people. For no sooner was it accomplished than it excited the attention of a new army of investi-

gators—the industrial chemists. The patent offices of the world were soon crowded with alleged commercial syntheses of camphor, and of the favored processes companies were formed to exploit them, factories resulted, and in the incredibly short time of two years after its academic synthesis artificial camphor, every whit as good as the natural product, entered the markets of the world, to establish there, for those who have eyes to see, this cardinal truth that no body of men can reasonably expect to permanently monopolize the sale or growth of a natural product on an export basis.

And yet artificial camphor does not—and cannot—displace the natural product to an extent sufficient to ruin the camphor-growing industry. Its sole present and probable future function is to act as a permanent check to monopolization, to act as a balance-wheel to regulate prices within reasonable limits. The necessity of this somewhat undignified rôle for a chemical process lies within the nature of the process itself. Every artificial synthesis of a natural product must have some starting-point, some substance upon which to build (Fig. 32). If that substance exists in large quantities in coal-tar, or in petroleum, or other cheap and everywhere available material, the future looks dark for the natural product. If, on the contrary, the starting-point resides in some material from which it is difficult to extract it, or which is itself in great demand or on a rising market, the utility or validity of the process is correspondingly

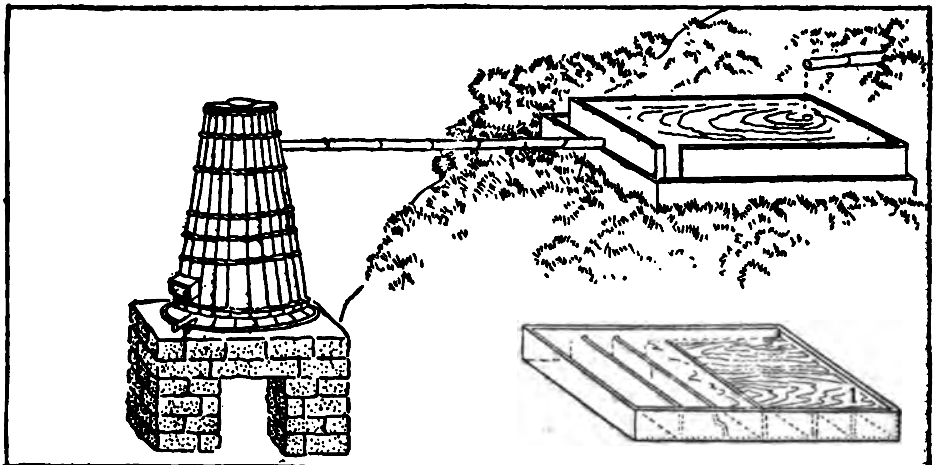


FIG. 32—A JAPANESE CAMPHOR-STILL

limited. Now, all the processes of artificially manufacturing camphor start with *pinene* or some allied substance. But the great source of *pinene* is oil of turpentine, and to any one who knows the enormous extent to which oil of turpentine is adulterated, the increasing demands for it, its increasing scarcity, together with the widespread alarm over deforestation, it needs no demonstration that now and in the future it will be on a constantly rising market. While it is undoubtedly true that new and improved processes will cheapen the price of synthetic camphor, it must always start on the basis of a parent substance which is too expensive, with an expensive plant, expensive reagents, expensive labor, and with the consumption of considerable power. What still further limits the power of the synthetic industry lies in the parallel factors of valuable by-products of the camphor-tree in the form of oil of camphor, and in a remarkable discovery which has improved the camphor-growing industry; of these I shall speak again.

Meanwhile, the Japanese were confronted with another factor equally valid in preventing the monopolistic control of the world's needs. There existed, belting the world, other lands having similar conditions of soil, rainfall, temperature, elevation, and cheap labor. *Camphor could be grown elsewhere.* In Ceylon preliminary experiments in the Botanical Gardens at Hakgala were so convincingly favorable to the planters that to-day thousands of acres of young camphor-trees lie here and there every-

where over the island, growing luxuriantly, and established permanently as a source of the island's wealth. Similar conditions are rapidly obtaining in Malaya. In Italy the *Laurus camphora* has been grown as a shade tree for a hundred years, and, stimulated by this monopolistic menace, Giglioli has recently, in a comprehensive monograph, *La Canfora Italiana*, not only demonstrated that the camphor-tree has been and may be grown with the greatest ease in many sections of Italy, and that its camphor content is well up to the normal, but he has, through a masterly exposition of the conditions of its growing, placed within the hands of the Itàlian people of the landed class a new and profitable source of an assured income. Particularly interesting are the experiments of the Biological Station at Amani, German East Africa. There the director of the station has not only readily succeeded in growing camphor, but through a certain discovery he has made he bids fair to have revolutionized the industry. In our own country the plant has been grown for years as a shade tree in California, and so it has, as I am informed by numerous letters, in Texas and Florida. In these States, too, the Agricultural Department at Washington has for some years conducted successful experiments in camphor culture, and to such an extent that it feels warranted now in devoting time to the elaboration of an efficient still for the economic extraction of the camphor, by which any American camphor grower may extract his

own material. In Florida there is a flourishing camphor plantation at Satsuma. In the island of Jamaica the successful growth of the camphor-tree in the Hope Gardens at Kingston attracted the attention of a scion of one of the oldest families on the island, and five years ago, in a favored valley of his estate, he planted his experimental seeds. There, among three thousand acres of earthly paradise, and in a home so old that its cellars are loop-holed as a buccaneering stronghold, he earnestly watched over what the Caribbean breezes and sunshine evolved of the race of old Japan. After five years of watching and yearly planting, it was found that the trees, one, two, three, four, and five years old, hundreds of them, were all strong, straight-limbed, glossy-leaved, flourishing with all imaginable health and vigor. The camphor-tree would certainly grow in Jamaica. But would it yield camphor and oil of good quality and in proper amount? The growth of a plant in a land foreign to it by no means infers that it will reproduce its essential oils. It is known, for example, that down in Mexico they have for years been transplanting from India the *Cannabis Indica*, or Indian hemp, the material of a powerful drug; yet after two or three years of growing it turns out that this tree invariably reverts to *Cannabis Americana*, the extracted drug of which is wholly different, and the attempt, therefore, is at present a failure.

In order to solve these questions, then, I brought back with me to the University of Kansas nearly a ton of

material, which we worked up to the last ounce. We extracted the best of the camphor and the oil of camphor from the wood of the trunk, from the branches, the twigs, the green leaves, the dry leaves, and the dead leaves, and we obtained results which afforded us profound astonishment and great joy. We thought we had made a great discovery, and as a matter of fact we had, though, unfortunately for us, these results had just been anticipated by the work of Messrs. Campbell and Eaton in Malaya, and by the director of the Biological Station at Amani, East Africa. Since, however, our results absolutely confirm the work of these gentlemen, and since they are so important to the whole great camphor-growing industry, I give them here. As a matter of fact, and speaking in averages, our results analyzed out as follows:

Wood	0.61% of Crude Camphor
Twigs	1.05% of Crude Camphor
Green Leaves	2.37% of Crude Camphor
Dried Leaves	2.52% of Crude Camphor
Dead Leaves	1.39% of Crude Camphor

These results are extraordinarily high, owing partly to the fact that the material had undergone a considerable amount of drying in its long transport from Jamaica to Kansas, and partly, too, I believe, to the ideal conditions that obtain in Jamaica for the growth of essential oils. But it is the proportional amounts to which I draw attention. The wood of the camphor-tree con-

tains an insignificant fraction of the camphor contained in the green, dry, and dead leaves. This is to be correlated with the indisputable fact, as proved by Mr. Malcolm, of Jamaica, and others the world over, that the leaves can be harvested regularly without any injury to the tree. These two facts, taken together, place both the huge camphor monopoly of Japan and its synthetic manufacture in Germany and elsewhere in a position that would be laughable were it not rather pitiful. Both types of organization proceeded on the assumption that the centuries-old traditional method of extraction was the only one. In order to continue it, the Japanese felled only trees fifty years old and extracted the drug from the wood only, leaving the leaves out of consideration. In order to carry out this destructive work, they ran deadly electric wires through the forests to keep out the savages; they placed armed men with every camp of camphor-workers, and they paid these workers 90 cents a day for a native Formosan and $1.99 a day for a Japanese. The price of labor in Jamaica is a shilling a day. Now, as a matter of fact, in a five-year-old tree the mass of its leaves weighs 7.05 per cent. of the total bulk of the tree. The proper method, therefore, without destruction to the tree, is to regularly harvest its leaves for their excessively large camphor content; costly expeditions into savage interiors and the total destruction of mature trees are wholly unnecessary. Not only so, but through the investigations of Herr Lommel,

of the Biological Station at Amani, there appears an additional fact of extreme importance. As he says, "the great desideratum in camphor-growing is to lessen just as much as possible the expense of harvesting the leaves. To strip them off the tree or the branches by hand is a time-consuming and more or less costly operation. If, instead of that, one can pick them up off the ground, the labor of harvesting will be minimized." He has discovered that the naturally fallen leaves of the tree contain an exceptionally high per cent. of camphor, and his conclusions the labors of Giglioli and our own absolutely support.

To everybody, then, living in the semi-tropical belt and possessed of suitable conditions of soil, rainfall, and cheap labor, camphor-culture, through harvesting and extracting the fallen leaves, offers generous returns, and returns, too, that are not likely to be lessened through overproduction, for each year brings new and increasing demands for both camphor and oil of camphor through the advances of industrial chemistry in discovering and providing new uses for both.

Because of these facts, then, it is little wonder that, following the recent report of Schimmel & Co., the great German house engaged in the manufacture of essential oils, the efforts both for the monopolization of camphor and for its profitable synthetic production are hopelessly defeated. The moral, of course, is "Look before you leap," into all the factors related to the production of

a natural product, remembering particularly that the biological and agricultural stations, that in ever-increasing numbers are dotting the surface both of civilized and uncivilized lands, have justified their existence many thousands of times over. Through their efforts a new industry has been added to the resources of many and diverse races of people.

To end as we began, if there are enormous pecuniary and material results to be obtained through forcing the products of our civilization on foreign peoples there is just as much material gain to be obtained through taking over from these foreign peoples their own disappearing forms of knowledge and forms of life and converting them to the needs and uses of our own civilization.

VIII

BREAD

"No man shall take the nether or the upper millstone to pledge: for he taketh a man's life to pledge."—*Deut. xxiv:* 6.

THESE words signify in a beautiful and very practical way the universal and enduring need of bread. Today, with exceptions so few that they horrify us to hear of, every man, woman, and child in America has his daily wheaten loaf. This wheaten loaf is the evolutionary product of innumerable centuries of baking.

The question, "When did man first eat bread?" might almost as well be answered by another, "When did man first obtain his molar teeth?" The ancient words "bread," "barm," "leaven," "loaf," "knead," "lord," and "lady" signify in their ultimate derivations the immense antiquity of the art of baking; in fact, the making of bread, together with the tanning of skins and the burning of pottery, is one of the oldest of earth's arts.

The housekeepers of America today make seventy per cent. of all the bread, yet the remaining thirty per cent. made by the bakers involves a capitalization of over two hundred and seventy millions of dollars. Any-

thing, then, that we can discover of the present-day status of the art of bread-making is of importance and of interest. The first known making of bread refers back to the prehistoric lake-dwellings of Europe, where there have been discovered the grains of barley, oats, rye, and wheat, together with the charred remains of cakes of bread and the rude stone grain-crushers and mealing-stones. It is true that these pellets of wheat and barley are but humble representatives of the highly bred grains that now glorify the farmer's field, and it is true, too, that the loaves were for the most part but of crushed grains, not true meal, and obviously made by being laid on the hot stones and covered over by glowing ashes, just, in fact, as the muleteers of Syria today make their unleavened cakes; but it was bread.

Since in Eastern countries a mixture of meal and water will begin to ferment in the course of a day, the value of leavened bread must inevitably have been discovered prior to civilization. We all remember the story of the flight of the Israelites out of Egypt, how "the people took their dough before it was leavened, their kneading-troughs being bound up in their clothes upon their shoulders" (Exodus xii: 34); leavened bread —*i. e.*, bread as we know it—must at that time have been universal. Early, too, must have been the specialization of the art of baking; first, doubtless, in the largest households, as witness the interesting story of that most unfortunate chief baker in Genesis xl; and afterward,

as the reader may readily find, into a definitely segregated trade, as in Hosea vii.

There have always been bakers, but, on the other hand, from the beginning of human time bread has always been baked in the home, particularly and definitely as the vocational duty of women. There thus appears this most curious and interesting of facts: that contemporaneous with the history of man from the earliest to the latest times there has been an unremitting conflict between home-made bread and the baker's loaf. The present-day outcome of this eternal war may be expressed in the fact given above: that the housekeeper make seventy per cent. of American bread. But how much does this depend upon the traditional enmity of woman toward the baker, and how much upon the traditional timidity of *paterfamilias* in expressing an opinion upon so delicate a subject? The interests of truth, however, and because it is a subject of such importance to every home, insist that some comparison shall be made between home-made bread and the baker's loaf.

The traditional idea of the bakery is that of dark, low-ceilinged, germ-laden rooms, in which men, wholly indeterminate in their periods of ablution, swelter among the flour, yeast, and dough, mixing, baking, and pawing over a crude substance adulterated with alum and wholly abominable when compared with the inviting, wholesome aliment of the home. Nothing could be farther from the present-day truth. The bakery, as we shall picture it

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here, does not represent the very best practice and, of course, by no means the worst; it does, however, represent good practice rapidly extending into universality.

The present-day bakery, then, is represented by a large, four-storied, modern building, with asphalted floors. In many rooms its walls are tiled, and in others they are lined with cork to produce equality of temperature. It is provided with beautiful enginery in its power-room, with a cold-storage plant and a cold-air plant.

Let us swiftly review the process. The flour is emptied into the hoppers in the basement, from which it is carried by conveyors to the fourth floor, where, after being vigorously sifted, it passes into a gigantic bin holding, say, seventy-five barrels. The descent of this flour floor after floor marks its transformation into bread. It is automatically withdrawn from the bin, automatically weighed, and automatically dropped into the mixing-machine. In this mixing-machine, with the requisite quantities of yeast, sugar, salt, milk-powder, and malt—if it is used—it is rapidly lashed into a homogeneous dough and subsequently automatically thrust into the fermenting-tanks; from the fermenting-tanks through hoppers down to the cutting-table below; from the cutting-table below through the various cutting-machines, forming-machines, and balling-machines; through the "proof-room" to the oven; and subsequently from the oven to the delivery wagons. The

words "automatically treated" must be understood as applicable in a large and generous sense. While it is not true that in the practice here described bread is absolutely free from the touch of a human hand, it is almost true; and to such an extent that it is obvious that in the best baking practice of the immediate future this ideal will be completely realized. The process is absolutely flawlessly clean.

Now, as for the materials. These are of the best. The flour is of the best brands, just such, in fact, as the householder uses, and so are the materials. While it is true that generally milk-powder is used instead of milk, and cottonseed oil instead of butter, these materials are clean, pure, and good for the purpose.

And what about the product? Compared with the bread of our grandparents' time, modern baker's bread of the best practice is certainly superb. The old-fashioned baker's loaf that was more holes than bread, and that modicum of bread of a tasteless, indigestible character, has been displaced by a loaf which in color, texture, flavor, and nutritious qualities is positively good.

But not best. Let us grant at once that the very best product of the very best housekeeper (*pace uxoris meæ*) excels in its excellences the best baker's loaf. But in this production there is no regard for cost either of time or money. If such a housekeeper were to count into the cost factors such as time employed, wear and tear, investment, fuel, failures in her product, stale bread,

and the prices and quantities of her flour, sugar, milk, and shortening, she would find its summation almost in excess of the price she would pay the baker. As for the average home-made bread, where temperatures are not controlled and qualities of constituents vary, it may assuredly be pronounced no better than the best baker's bread, as obtainable in large cities. Outside of the instance in which high art and regardlessness of cost figure, home-made bread may be said to pay, possibly, in the case of a mother of a large family who bakes her own bread. As a statement of simple fact, home-made bread must ultimately disappear before the increased efficiency of the baker, the growing accentuation of the servant problem, and the spread of co-operative principles in housekeeping; the bakers will make the bread just as other manufacturers now make the pickles and the mustard and the butter.

Has the best bread been made either in the home or in the bakery? Certainly not. Both in the home and in the factory baking is practised essentially as an art. It has still to become a science. In saying this the large bakers will not agree with me. They will point with triumph to the thermometer which every good baker carries about with him, to the rigorously exact weighing of materials, and to the sternly regulated periods of mixing, fermenting, and baking, and the uniformity of their product. But these statements convey all they have to show of progress. In fact, the bakers, as with

certain other manufacturers, in standardizing their process are in danger, so to speak, of *crystallizing* it. They are not themselves, except dimly, aware of the scientific possibilities of their art.

In order to see not only how true this is but how interesting are the problems in themselves, let us review the process. Baking is concerned with some of the most recondite problems in contemporary science.

First, there is the flour. Two flours may be identical to all appearance in color, smell, feel, and granulation, and yet one will make a fine, light, large loaf, and the other a poor, heavy one. It must strike the reader, in view of the hundreds of millions of dollars involved, that it is an important and regrettable fact that neither the baker, the miller, nor the man of science can tell just why—yet so it is. The difficulties involved in answering such a question depend upon the complex nature of flour. Flour contains starch, gluten, sugar, soluble albuminous bodies, fats, oils, mineral matters, such as phosphates, fermenting enzymes, and bacteria. Variations in the quantities of starch in the flour doubtless do affect the quality of the bread, but to a minor extent. The gluten is more important; it is, in fact, certain that the quality and flavor of the bread depend upon the gluten of the flour. And yet how difficult it is to understand!

Gluten is a highly nitrogenous, tough, sticky, elastic material which shows its characteristics only when the

flour is made into dough. As the dough rises to the baking temperature it puffs itself up into a round ball which sets on the outside into a hard skin or crust, while within, owing to the steam, it lies in a system of fine threads and meshes, in the interstices of which, in the bread, lie the granules of starch. The ability to make a loaf of bread at all evidently depends on the fact that the elastic, sticky gluten at a lower temperature resists the escape of the gas evolved during the fermentation, and so becomes puffed up into lightness, while at a higher temperature it becomes converted into digestible material and *sets*.

This is the philosophy of baking, but as with other philosophies, it is but the beginning of our explanations and our troubles. If the rising power of the bread depends on the per cent. of gluten in the flour, the flours of maize, barley, and rice ought to make good bread, for they contain more gluten than does wheat. Such flours, however, will not make bread. Evidently, then, what is gluten in one flour is not gluten in another, and evidently, too, we do not know what gluten is. About it, however, this much is known, that the glutens from rye, maize, rice, barley, buckwheat, and wheat all contain varying quantities of two substances, chemically combined or mechanically mixed, nobody knows, called respectively *gliadin* and *glutenin*. It turns out, too, that among the grains grown by man wheat contains by far the highest per cent. of *gliadin*. *Gliadin* is a very

sticky substance, while *glutenin* is not; *glutenin*, however, seems to form a network to which the *gliadin* adheres, and the two together, like a concrete of which the *gliadin* is the cement, seem to constitute the framework of the loaf. Why, then, should not the baker say that the size of his loaf depended upon the relation between the *gliadin* and *glutenin* of his flour, and buy his flour accordingly?

The idea was fascinating in its simplicity, but it was based on too restricted a purview. It is partly true, but as a complete explanation it is fallacious. You see, flour is so complex. Every flour contains naturally between one and two per cent. of sugar. This sugar it is, as we shall see, that the yeast utilizes in the fermentation of the dough and out of the destruction of which the gas is produced. It has been discovered that the volume of the loaf depends on the quantity of sugar available during the final stages of fermentation, and hence it has been inferred that the strongest flour is that which has the highest per cent. of natural sugar; this is partly true, perhaps fallacious also, as a complete explanation. Still again, flour contains varying quantities of soluble albuminous bodies, as well as small quantities of fats and oils and mineral matters such as phosphates, and finally of fermenting enzymes, all of which influence not only the size of the loaf, but, as well, the quality, flavor, and texture of the resulting bread.

Obviously the baker does not know how to buy his

flour. In order to better his flour he, or the miller for him, frequently *blends* it, and thereupon new troubles begin. By mixing flours it is undoubtedly impossible to regulate one factor without sending topsy-turvy half a dozen others. Moreover—and this is a strange thing —by mixing flours the baker does not get a summation of the qualities of each, but, on the contrary, a completely different flour. The reason for this is absolutely outside the reach of contemporary knowledge. Is it, then, to be wondered at that the baker is virtually compelled to buy his flour in quantities of from one hundred to two hundred thousand barrels at a time without any prior chemical understanding of the validity of his purchase? He depends, with the possible exception of a crude baking test, absolutely on the character of the miller, and the miller—is the miller. When into this mass of flour he places his yeast innumerable additional difficulties flock about his head.

Yeast? From the time of Pasteur it has been the subject of innumerable investigations, and as yet, even today, we are but on the fringe of knowledge. This is particularly true as regards the ferment for bread; for, while millions have been spent on the chemistry of fermentation, this fermentation has had to do essentially with beer and wine; bread has shared only the incidentals of the investigations. Still, to-day, the interests involved in the manufacture of yeast are highly specialized. Particularly is this the case with the

Netherland Yeast Company, whose factory efficiency it is a privilege to inspect. To the seat of this company at Delft come from all parts of the world maize, barley, and rye. The rye is made to undergo a fermentation which develops lactic acid together with considerable quantities of sugar. This lactic acid-sugar mixture is then used as the medium upon which the parent yeast is grown. While the sugar of the mixture affords food for the yeast, the lactic acid constituent acts as an anti-toxin to the various poisonous and bad yeasts and ferments which would normally develop. Meanwhile there has been prepared the immense mixture of saccharine materials, maltose, dextrine, etc., resulting from the action of the malted barley upon the corn; and into this mixture is thrown the selected yeast. There results an immediate fermentation on a huge scale. The yeast is thrown off as a great mass of scum, which is filtered free of water, dried, packed, and sent to the bakers. The liquid mixture, the alcohol, makes its way into gin or into the denatured alcohol of commerce. What goes to the bakers under this process is a mass of innumerable millions of globular organisms, so small that five thousand of them placed in line would barely measure an inch. Everybody knows the essentials of their action. They convert the sugar of the dough into carbonic acid and alcohol, and at the same time there are formed small quantities of glycerin and oxalic acid. The carbonic-acid gas puffs up the dough into lightness,

the alcohol has a similar effect in the oven, and in addition checks to a slight extent bacterial fermentation, and, as well, has a softening effect upon the gluten of the dough, thus increasing its power to hold the gas which is produced. The bodies of these little organisms contain invertase, which is able to convert sugar-cane into invert sugar; they contain zymase, which is the substance that transforms the sugars so produced into the large quantities of carbon-dioxide and alcohol; and they contain, as well, certain other ferments that convert the protein matter of the bread into material of grateful taste and nutriment. The yeast organisms do not carry out this work *per se*, but because of these substances they contain. In order that they may rapidly multiply to efficient working, the dough contains, almost providentially one might say, the requisite substances—soluble proteids to afford them nitrogenous food, sugar, without which they will not work at all, and mineral substances which accelerate their action. All this is very pretty philosophy, what we know of it, but, as a matter of fact, the very outposts of a true knowledge of bread-making still remain unconquered.

There are many different strains of yeast; what are the best for the bread concerned? What is the nature of the best soluble proteids for yeast-food, and what should be their proportionate quantity? What mineral substances best accelerate the action of yeast? What is the actual action of yeast in the gluten? What is

unquestionably the proper temperature of bread fermentation? What is the best method of exorcising the influence of maleficent bacteria and of accentuating or utilizing the influence of bacteria that are beneficent?

All these and many other questions must be answered before we shall know even the causes that produce the highest nutriment, the texture, the crumb, the flavor, or even the bloom on the crust. It is apparent that we are still far from the ambrosial confection of the future.

Meanwhile, science is eagerly desirous of obtaining an entrance into these most difficult problems. In this connection it is a particular pleasure to refer to the results obtained by the National Association of Master Bakers' Fellowship in Industrial Research, established at the University of Kansas. This fellowship, yielding five hundred dollars a year for two years, together with an additional consideration, was conferred upon Mr. H. A. Kohman. During its tenure Mr. Kohman has made himself favorably known to every progressive baker in the United States. His first achievement dealt with the problem of stale bread, which in the case of many bakers amounts to as much as eight per cent. of their output. This stale bread today is sold from one to two cents per loaf. Mr. Kohman evolved the idea of treating this stale bread with small quantities of malt extract, by which its starchy constituents are converted into fermentable sugar. After treatment with the malt, it is

filtered off and the sugar and the malt together used in the next batch. Mr. Kohman thus, in large measure, saves and eliminates the use of sugar-cane by the baker. He has left behind, as residue of the loaf, all the gluten, in the form of a beautifully pure and pleasant substance. When he has found a practical use for the enormous quantities of gluten thus obtained he will have transformed the stale bread from a loss into a profit. Next, he has discovered, isolated, and grown pure cultures of the bacterium concerned in the fermentation of salt-rising bread. He has grown this pure culture in large quantities, and he has made in his laboratories salt-rising bread of perfectly uniform quality day after day. Finally, he has taken his process and ferment down into one of the largest wholesale bakeries of the United States, and he has turned out the bread resulting from this process, at the rate of a thousand loaves a day, into the market in order to test it. The market received it gladly and without one instance of objection. To any one who understands the past hopelessness of attempting to make salt-rising bread on a large scale, this is a most notable achievement. This salt-rising bread, which in many sections of the South and West is the only bread, has its devotees everywhere, from Governor Stubbs, of Kansas, who offered his daughter a prize of fifty dollars to make it, to the many senders of the letters to the Department of Industrial Research, eagerly requesting samples of the ferment. In the past the

FIG. 34.—CROSS-SECTION OF "SALT-RISIN" BREAD

FIG. 33.—LOAVES OF "SALT-RISIN" BREAD MADE BY THE NEW BACILLUS

housekeeper who could make good salt-rising bread had a great reputation; now anybody may make it, and of uniform quality. It is intensely interesting that this splendid "old-fashioned" bread should be due not to yeast at all, but to a specific spore-bearing bacillus—and that this bacillus, dragged out of the empty air, should be in the future a marketable and useful commodity and the basis of a new industry. Figs. 33, 34.

Contributions to the chemistry of bread are now appearing in the journals of science with ever-increasing frequency—many of them interesting and promising of future results. One investigator has been studying the cause of the color in brown bread, another the survival of pathogenic bacteria in bread after baking, still another the proteolytic ferments of wheaten flour and their relation to baking value. Much investigation is being given to-day to the perplexing problem of methods of estimating the strength of flour, and still more, perhaps, to the determination of the relative nutritive values of different kinds of bread. In the Patent Office particularly one finds a special activity in the elaboration of "queer" breads and medicinal breads—breads containing iron, albuminous breads, and breads made up with an attempted regard only for nutritive values. An apparently favorite method of making albuminous bread is to mix with the flours of wheat and rye large quantities of boiled fish and potatoes, after which, as a dough, it is fermented and baked. A new flour appearing in some

patents consists of the meal of the sweet-potato, banana, and cassava. Out of the many investigations in progress one is impressed with the idea, hardly more than nascent as yet, of the possibility of altering bread into, or adding to it, substances of medicinal quality. By all odds the greatest present-day investigation relates to the permissibility of the process of bleaching flour with substances such as ozone and oxides of nitrogen. Is it harmless or is it vicious? Large interests are involved, and the whole investigation illustrates typically and most regrettably the fact that too often on the receipt of large remuneration the man of science is unable to see with an eye single to the truth. As for the young chemist, seeking for an *arbeit*, he may find in the bread he daily eats the chemical investigations of a lifetime.

But if men of science are becoming interested in bread, so, certainly, are the bakers. It is true sometimes, as with men of science, their material interests blind them to simple fact. This is notably the case in "the wrapped bread" question which has wrought the trade into a turmoil. To the consumer it would seem an obvious desideratum that the purity of his product should be insured by a wrapping of impervious paper at the bakery itself. The trade is divided on the subject, one side maintaining the validity of the advantage, and the other that, by wrapping, the flavor of the bread is impaired. In order to test the matter the writer fed sam-

ples of their bread, wrapped and unwrapped, to three representative bakers, and as they were positively unable to detect the slightest difference in either flavor or quality it seems plain that wrapped bread has come to stay. Of course the actual reason for the objections lies in the fact that it costs about 7 per cent. of the selling price of the loaf to give it this impervious wrapping, and that this would mean a corresponding decrease in the size of the loaf. But the whole *collegium pistorum*, so to speak, is interestingly illustrative of the psychology of trades. As a class they are curiously alike, and differentiated from the followers of other trades as men of quiet diligence, deeply religious, sincere, and idealistic. To the aspirations of the bakers to better and ever better practice their trade journals bear ample witness. But to harry the bakers has always been a favorite game. The statute-books, from the remotest time and in all countries, have sternly and minutely governed the baker, the materials and quantities he should use, how he should bake his bread, what should be the size of the loaf, its price, and where and to whom he should sell it. Witness this old fragment from an Act of Council at Glasgow; it is typical of hundreds of others:

"And it sall not be lesum to nayne traweller that brings breid to the mercat to sell ye samyn to nayne outtentowneris man in laides [loads], crieles [baskets], nor half crieles jumgit ye gedder [in heaps] quhile the inhabitants of the towne be first servit, and XII houris struken, and that na man of man sell the breid that

is brocht to the towne bot the bringar of the same allanerlie [alone], and that na traweller bring breid to ye towne to sell but IIIId breid and twapenny breid," etc., etc.

In these days, however, the restrictive panary laws that have been passed in many States and localities are only too often unduly onerous and essentially unjust. The fact that bread is the staff of life is particularly unfortunate for the baker in making him a popular target for legislative enactments. But it should be remembered that the baker with his loaf is at the beginning of a procession leading back to the land. There is the farmer with the prices of his agricultural machinery and his labor—the railroad with its transportation rates—the grain-elevator—the miller—the stock manipulator—the commission merchant—the yeast people—and for the baker himself the increased prices of his labor, power, and machinery. All such on a constantly rising scale of cost must be satisfied before the baker receives his modicum of profit—and the profit is certainly not excessive. Did the reader ever see a really rich baker? There are not many such, for large returns rest wholly on a tonnage basis. If the prices of material, labor, and power continually rise, the price of the loaf must rise with them, or the size of the loaf must decrease; there is no other solution, "For the Scripture saith, 'Thou shalt not muzzle the ox when he treadeth out the corn, and the laborer is worthy of his hire.'"

IX

RELATION BETWEEN CHEMISTRY AND MANUFACTURE IN AMERICA[1]

IN presenting some reflections on the present-day relation between chemistry and manufacture in America, it is necessary, both because of the large scope of the subject and because the quotation of individual instances would be offensive, to proceed in a spirit of broad generalization; the validity of these generalizations will depend on the reasonableness of their context. Furthermore, it should carefully be prevised that there is no attempt to take a dogmatic, *ipse dixit* attitude, and, related to most of the statements that will be made, there should be carefully understood the words *exceptis excipiendis.*

The problems to be discussed are in large measure the result of a lack of mutuality between the factory organizations on the one hand and the universities and technical institutions on the other. This lack of mutuality depends primarily upon a lack of understanding on the part of factory organizations of the advantages that are to be derived from the employ-

[1] An address delivered before the New York section of the American Chemical Society, on January 6, 1911.

ment of sensible chemical research, and of a corresponding lack of understanding on the part of institutions of learning of the proper training and type of men that are requisite for the successful practice of chemical industrial research in these factories. A mutual understanding in America, at least, might speedily lead to co-operation, and co-operation to a sensibly functioning co-ordination. The American factories, taking them by and large, and making such distinguished exceptions as could be numbered on the fingers of both hands, certainly do not have co-ordinating relations with the universities, such, for example, as we find developed in Germany. Furthermore, in so far as industrial research is concerned, they do not have co-ordinating relations with one another. There exists no common consciousness among the corporation officials of this country of the proper methods of conducting factory research. In order to show how true this is, permit me to place before you the results of a preliminary inquiry which was initiated last spring as to the conduct of factory bureaus of research:

First, the entirely significant fact should be stated that at that time there existed no available list of the research bureaus of this country connected with factory organizations. After writing unavailingly to various reasonable sources, such as the *Journal of Industrial and Engineering Chemistry*, the *Bureau of Commerce and Labor*, the *Census Department*, etc., it became

necessary to inquire here and there everywhere among industrial colleagues for individual and incidental information. Owing to their kindly co-operation, there was eventually provided a list of some seventy-five corporations possessing either bureaus of research or individual research chemists. From these corporations there were received some forty-five frank replies, given on the understanding that each reply was to be confidential and was to be used only in a summation of results. The results of this preliminary inquiry are illuminating of the chaotic conditions that pervade factory research.

It may be interesting to know that in very few instances are contracts made with chemists. In general, the chemist is "hired" by the week or by the month. There are a few, a very few, instances of contracts of one or two years' duration, and one instance of three years. Of security of tenure there is virtually none, except in the rare instances of contract. With reference to the question of security of tenure, one meets constantly such statements as "Yes; if ability and energy are shown"; "Yes; if he makes good, otherwise not"; "A man's record and value are his only security"; "As long as work is satisfactory," etc., statements which seem reasonable until one considers, as will be seen below, the lamentable conditions under which, too often, these men work.

Next, as to the salaries, or, as a term which is more fitting on the whole, "wages."

In most instances wages are paid by the week: translated into terms of monthly payment, the young graduate receives sums ranging from forty-five to one hundred dollars. This latter statement exemplifies the extraordinary diversity of conduct and the chaotic conditions that everywhere prevail in factory research. So far as one may strike an average among such qualitatively different factors, sixty dollars would perhaps be representative. The question, "Does the initial salary vary with the degree possessed?" elicited the surprising information that in a large number of cases the corporation cares very little, or not at all, what degree the man may have; as one official said, "We call them all doctors, anyhow." What is important to the corporation—vice-president, general manager, or what not—is his individual impression of the man and of the likelihood of his "making good." Of course here, as elsewhere, there is the widest diversity of practice: in one bureau of research "the degree of B.S. corresponds with fifty to seventy-five dollars, while the Ph.D. as nearly as can be stated varies from one to two hundred dollars"; or, again, "Yes; a man with a higher degree than B.S. starts with greater salary, though it depends on his other qualifications." In industrial practice the particular degree possessed is of much less value than young men understand.

In practically no instance is there any mechanism of promotion.

Related to salaries, and as a natural sequence, there are the hours of labor; and typical of the diversity of practice and the lack of any common agreement as to what is fitting, I append here a fraction of the list of answers: 8–12, 1–5.15; 7½ hours per day; 9 hours; 8–12 M., 1.15–5.15; 9–4.30; 9 hours; 8 hours; 8–5; 8–5; 7.30–5; 9–12, 1–5; about 8 hours daily; 7.30–11.30, 12.30–5.30; 7.30–11.30, 12.30–4.30; 8.45–5.30; up to 24; 8 hours daily; 8½ hours daily (etc., etc.).

Is the research man on the same basis as factory employees in being held rigidly to these hours? There are as many *Yeses* as *Noes*. Relative to hours of labor, and because often enough the young graduate has to choose between an industrial and an academic career, there is the question of vacations. The answers run along as follows:

Two weeks; ten days; two weeks to month; two weeks; seven weeks; generally get what they demand; two weeks for men who have been with us six months; two weeks; one month; two weeks; ten days if we can spare him; two weeks; two weeks; two to three weeks; ten days (etc., etc.).

The question: "Do researchers take a half-holiday on Saturday?" is answered mostly in the affirmative, though there are some negatives and answers such as follows:

"Yes, during June, July, and August."

"During summer months the research men take a half-holiday on alternate Saturdays," etc.

You will probably be surprised to know that there is practically no mechanism of promotion for chemists such as often obtains in factories for officials. One corporation does state that "each man is considered every six months, and if previous work warrants the action, he is recommended to the manager for a raise of salary." Another corporation "is governed only by results"; still another says that "promotion is entirely for merit; seniority counts for little with us." One corporation adds one dollar per week every six months up to a maximum of forty dollars a week.

An interesting result of this inquiry appears in the reply to the question: "Do the members of the bureau sign a contract resigning all rights to any discoveries made while in your employ?" The prevailing answer is "Yes." It is a matter of surprise that contracts embodying resignation to rights of discovery were so prevalent. In reply to the question as to whether any additional remuneration was granted to successful researchers, the prevailing answer was "No," with an occasional "increased pay." Two corporations speak of "opportunity to acquire stock" or "a cash present," but there is no instance of royalties or a share in the profits.

The responsibility of the director of research to a corporation is generally responsibility to one official therein; but it may be to the president, the vice-president, the superintendent, the consulting engineer,

or the manager of the works; in certain cases his responsibility is apparently quite indefinite. The directive power of the director is curious in its indefinite character; often it is not directive at all.

The short time afforded for this address might be wholly taken up by a consideration of the interesting answers offered to many questions.

The inquiry, however, was for personal purposes, was wholly unauthorized and preliminary in character. Reference is made to it here merely to an extent sufficient to justify a statement which will be made later on. The results obtained, while sufficiently demonstrative of uninformed and indeed chaotic conditions, are only inferentially demonstrative of inefficiency in contemporary factory research.

Personal observation, however, for several years leads me to state that presumably ninety-five per cent. of so-called factory research is worse than loss, *worse than loss* because the failure of the individual instance places a finale on the possibility of that particular factory to understand the advantage of applied science. The normal failure that attends factory research is due to ignorance of the canons of judgment in choosing chemists, inexperience in dealing with them, and a generous lack of knowledge of the facilities with which it is necessary to furnish them—laboratory, library, and living facilities. I have met tragical instances of chemists possessed of high training, creative power, and practical character,

working under the most shameful conditions, burdened with routine drudgery, subjected to the interference, and orders even, of factory foremen, and what is even worse, working under an entire misapprehension and ignorance on the part of the officials of the company as to their possibilities and value. I have seen them working under every circumstance of discouragement, inadequate facilities, and bad treatment.

On the other hand, I have met equally tragical instances of good corporations employing chemists, or "chemists" who were unfitted or unqualified for the work they had to do—"fakers" masquerading as chemists, chemists of the "Brahmin" type—analytic chemists trying to do synthetic work and *vice versa*—chemists with scholarship but no creative power and chemists with creative power but no scholarship—chemists with both scholarship and creative power but lacking in the personal or masculine qualities necessary to govern workmen, manage foremen, or to commend themselves to the company's officials.

On the basis of the inquiry which I made, a fraction of which is inserted above, and on the basis of a fairly extended personal observation, I urge upon this society the advisability of establishing an authorized comprehensive investigation into the present conditions that obtain in industrial chemical work, as these conditions refer both to routine and to research work.

I suggest that a commission formed for such a pur-

pose should investigate not only elementary matters, such as salaries, contracts, hours of labor, vacations, laboratory space and equipment, library facilities, relations of chemists to workmen, foremen, officials, etc., but that it should proceed to investigate the living conditions of factory chemists—*i. e.*, their homes; their social status in the factory family; the degree to which they are permitted to give publicity to their researches; the extent to which they are encouraged to attend the meetings of the learned societies; the time they are given for reading contemporary discovery; the extent to which routine men are attempting research and the amount of routine work required of real researchers; the extent to which corporation chemists are admitted to the results of their researches, etc.

The results of an accredited commission on such a subject could hardly fail to be illuminating and important to the five thousand members that constitute this society. If, further, this commission, on the basis of the best practice discovered, were to build out of this investigation a carefully formulated statement of recommendation, it would be welcomed by chemists and corporations alike. The fact is that at this time many corporations are deeply puzzled as to what to do with their chemists—how to fit them into the discipline of the organization without injuring their spontaneity.

An inquiry recently instituted among the universities enables me to state that the young men pursuing

the study of chemical engineering are few in number when compared with those in mining, electrical, civil, and even sanitary engineering. The reason for this lies in large measure at the door of the manufacturer, for, as stated above, he does not understand the conditions he must meet to insure the chemist he employs successful and happy functioning. In some measure, too, it may lie at the door of the university, for it sometimes happens that the director of the courses in chemical engineering is an engineer, not a chemist, and in cases where its responsibility is under the chemical department the director is generally "academic" in quality; in either instance the course may lack the training and inspiration necessary to send good men into industrial chemistry.

This is unfortunate at this time, for in the coming business contraction which informed opinion leads us to expect, while constructional work will diminish with a consequent lessened demand for engineers, industrial research will flourish. It is in hard times that a wise corporation spends money for the elimination of waste and for progressive factory practice.

Let us now consider briefly the extent to which this widespread inefficiency in industrial research is due to the university. The present-day vice-president or general manager of a corporation, however astute he may be, and, in fact, practically always is, is extraordinarily ingenuous when it comes to "hiring" a chemist.

Not infrequently he will write for one to the university which, let us say, his son attends. I do not speak disparagingly, nor with the least hint of disrespect, of my university colleagues when I say that the importance of the matter and mere candor impel me to state that it is at this point that his troubles begin. His application to the university is handed to the professor of chemistry. Speaking in generalities, and speaking most decidedly *exceptis excipiendis*, the professor of chemistry, no matter how distinguished he may be, is not infrequently a gentleman interested and concerned wholly with pure science. He has sometimes, either consciously or unconsciously, the attitude that the utilization of science to human needs is more or less degrading to science itself. In addition, he is a man who vibrates between his home and his laboratory, and generally has but little, if any, real knowledge as to the requisites for an industrial chemist. He is, often enough, fundamentally, both through temperament and education, incapable of making a wise choice for the manufacturer concerned, and he may proceed to nominate for the position in question some man for whom he has the least use. He does not understand that success in genuine industrial research presupposes all the qualities which are applicable to success in pure science, and, in addition, other qualities more or less unessential in the university laboratory. Perhaps I may be permitted to suggest that the difference between industrial chemistry

and pure chemistry may be compared to the difference between poetry and prose, in the sense that in order to write good poetry it is essential to possess all the qualities of the prose writer, together with others superimposed upon them. The canons of judgment in the choice of an industrial chemist appear to be:

(1) Training (Scholarship).

(2) Creative Power.

(3) Masculine Qualities, which enable the chemist in the factory to deal with workmen and govern foremen.

(4) Personal Qualities, as they affect his relations with colleagues and officials.

(5) Personal Integrity.

(6) Practicality.

(7) Health.

In proceeding to nominate a candidate for an industrial position, it has too often been obvious to me that the professor of chemistry has nominated his man on the basis of scholarship alone.

I venture to suggest that a committee authorized to investigate the conditions that obtain in present-day industrial chemistry could not do better than to include in its investigation the relations that the universities have to industry—or the lack of these relations. There are many and puzzling important problems in this connection. As stated above, there are the canons of judgment which a university should exercise in nominating men for industrial positions. Then there is the question

as to how much a university should regard its own selfish interests in refraining from nominating men who are actually or potentially on its instructional staff. Still again, there is the question of "release"—*i. e.*, the conditions on which a university may legitimately be expected to release a member of its staff to accept a more advantageous offer. There is certainly no consensus of opinion on this subject, for where the head of one chemical department may regard it as an exasperating compliment, another is likely to consider it an outrage. Personally I believe, *pace* the Carnegie Foundation, that a university, outside of its business offices, is not a business organization, and that the question of release should be looked at from the standpoint of the best interests of the man concerned, with, of course, an eye to a more or less suitable substitute.

A problem of extreme importance, and one to which I have never seen attention drawn, is the extent to which outside industrial or commercial work is permissible to the instructor in the chemical department of a university. Most professors or assistant professors of chemistry have from time to time offers of routine or research problems, generally attended with the offer of a microscopic remuneration, for industrialists are prone to believe that professors "love" to do such things. Now, we all know that the more the professor becomes involved in money-making outside the less value he is to his students; we know, too, that unless he is engaged in research of some

kind, whether "pure" or "applied," he is possibly of still less value to his students, and, finally, we know that his university salary, whatever it may be, is inadequate to his needs. An extrinsic but important consideration is the fact that carrying on outside work at the expense of the university plant, and at a low remuneration, because of his salary, he is taking the bread out of the mouths of his professional brethren, who have to pay for *their* laboratories, apparatus, reagents, and books. I ask again, to what extent may the professional chemist do commercial work and what should be the scale of his remuneration?

Closely allied with this problem is another that lies within the university itself. I refer to the differences existing in the university between instructors having vocational opportunities outside and those that have not. There seems to be a tendency on the part of universities, in order to obtain first-class men, particularly in engineering, physics, and chemistry, to pay higher salaries to men having vocational opportunities and at the same time to permit them to exercise their vocation. This, not unnaturally, the professor of Latin or philosophy resents. It would be interesting to see the whole matter threshed out.

Another matter of serious moment, particularly as it refers to commercial routine laboratories, has to do with academic instruction in chemical analysis. I may say advisedly, on the basis of numerous communications,

that there is considerable dissatisfaction over the type of instruction that in many instances is offered young men who after graduation enter commercial laboratories in positional capacities—dissatisfaction with antiquated and cumbersome methods that are taught and with the neglect of the time element in making analysis—dissatisfaction, too, over the tardiness with which university laboratories adopt new valid methods and apparatus, and over their neglect to teach their students some sense of proportion in distinguishing between accuracy and *practical* accuracy. Now, it is within the knowledge of us all that young men can never become chemists until they are first trained and disciplined into the exercise of the last fraction of accuracy that is in them. On the other hand, the university can no longer consider itself as apart from life, or as other than, in part, an institution for fitting young men with opportunities for life. It would seem that it is the duty of a university to fit men for positions as practical analysts as well as to fit them for practical engineering. To what extent should the schools conform in their methods of teaching analysis to practical considerations? This is a problem.

Finally, in this connection, and as a matter of personal opinion, it seems regrettable that chemical instruction should be so largely analytic in character; I mean by this that there seems to be not so much a disproportionate amount of chemical analysis taught in the academic courses, though certainly there is a great deal

of it, but that the other courses partake to such an extent of the analytic character in their methods. One wanders through course after course—not formally analytical—courses such as metallurgy, advanced inorganic chemistry and physical chemistry and physiological chemistry, only to find that they are taught analytically by analytic-minded men.

It is for this reason that I attach so much importance to the discipline and methods of organic chemistry, for organic chemistry is almost the sole subject in the chemical curriculum in which a student gains educational training in synthetic working and synthetic thinking. Now, in industrial chemistry the fields that most need research, and that in consequence offer the best opportunities, are in large measure organic—tanning, starch, glue, soap, essential oils, petroleum, and so on almost indefinitely. Furthermore, both in the organic and inorganic fields of industrial chemistry, and outside of the routine testing-laboratories, the problems that are perhaps most important to industrialists are *synthetic* problems. This is naturally the case, for the art of manufacture is fundamentally "making things." Yet the men whom the schools furnish to solve these problems are for the most part men so drilled in analytic habits of thought and work that they cannot naturally and efficiently act or think synthetically. Glass men want new glasses, the metallurgical people new alloys, the enamel workers new enamels, and so on; and yet

too often the men appointed to the task are beaten before they begin by their very habits of thought. I do not wish to attach too comprehensive a validity to this remark, but I believe that there is "a soul of truth" contained in it. Presumably, the ideal industrial chemist would be a synthetic man, carefully grounded in analytic work.

1911.

X

ON THE RELATION OF THE UNIVERSITY OF WISCONSIN TO THE STATE

REPORT to Frank Strong, Ph.D., Chancellor of the University of Kansas. Made at the Request of Walter Roscoe Stubbs, Governor of the State of Kansas, 1909.

SIR,—At the beginning of this report emphasis ought to be laid upon the motto of the University of Wisconsin as expressed in the words of its president—"The University an Instrument in the Upbuilding of the State."

After observing the work of its many faculties, one takes it for granted that the university must consider as its main function the adequate instruction of the four thousand young men and women who frequent it. Such an idea, however, would be erroneous. It is true that the university does regard it as its duty to stand as the pinnacle of the educational system of the State, and to so furnish itself, both in staff and equipment, that in the scope of the instruction offered, and in its

quality, it stands second to no university in this country. But alongside this duty there go two others on a parity of importance: One is the creation of knowledge, either pure or applied, for the university recognizes no distinction; and the other is the dissemination of knowledge both pure and applied by co-operating with and supplementing all other educational institutions in the State. It is only by grasping the fact that these three functions are not merely ideally, but actually and practically, on a parity that one can understand the University of Wisconsin.

The consequence of its outside activities is a situation that cannot be completely estimated. The fact is that the activities of the University of Wisconsin so ramify throughout the State, that its influence is so interwoven with the thoughts and conduct and daily lives of the people of the State, that "to find out what the University of Wisconsin is doing for the State" in accordance with your instructions, is nothing short of impossible. Certainly, these activities and influences cannot be estimated in figures, nor can they be estimated in facts; in all kinds of intangible but very real ways, the university has become a necessary part of the body of the State.

It will be understood, then, in what follows, that the outside activities of the university are not by-products, but are, on the contrary, a part of its normal functioning, and next, that it is impossible to estimate or even

to formulate the full results of these outside activities.

These services of the university to the State are the services of the members of the staff, and so soon as these services are considered an important factor appears.

The University of Wisconsin demands on its staff the highest quality of instruction, and the most authoritative, anywhere obtainable. It realizes that to obtain this really expert instruction it must compete, particularly in certain technical fields of knowledge, with industrial corporations, and, in consequence, it seems to have laid it down as a principle that in order to obtain this expert talent for the State it is wise not to burden it with too much instructional work in the university, but to permit and even to encourage its outside activities, either in research or along industrial lines. It must not be understood by this that the activities of the members of the staff are selfish. Nothing could be more mistaken; but it is obvious that it would not be reasonable to expect to limit a man of expert knowledge who can make say twenty or fifty thousand dollars a year to his university salary. As a matter of fact, there is a large amount of gratuitous and unselfish work done by the staff for the State.

(1) The university activities are prominent in the various State bureaus and commissions, and these activities may be divided into classes.

SCIENCE HALL, UNIVERSITY OF WISCONSIN

(a) State boards with university men as members, either paid or unpaid.

(b) University men employed as experts by State boards, either paid or unpaid, and either permanently or occasionally.

(2) There are certain departments of the university doing extra university services for the State.

I shall review some of these varied activities.

THE LEGISLATIVE REFERENCE BUREAU

It is safe to say that the legislator who would at this time attempt to limit the activities of this department would be made to regret his temerity. I have never been more impressed with the feeling of a universal expression of commendation for good work than in connection with this bureau. The bureau itself was founded on the proposition that the legislator, however honest he may be, and however successful he may be, and generally is in his business or profession, goes to the Capitol ignorant, on the average, of existing laws and procedure, knowing little of economic principles, with no experience in legal forms and unskilled in the accurate use of legal phraseology. The laws which he makes are thus only too often *amateur*, both in substance and in form, while after being passed they must of course meet the best legal talent of the country interested in their destruction. In order to help the legislator, in order to bring to the making of laws some-

thing of the same grade of experience and training and talent possessed by the administrative part of the government in interpreting them, this bureau of legislative reference was founded.

WHAT IT DOES

It gathers laws and cases upon legislative subjects from all parts of the world and arranges them in such fashion that they are readily accessible on a comparative basis.

It obtains from every available source data upon the actual working of similar laws in other States and countries, so that valuable suggestion may be afforded for proposed legislation.

In advance of every session special efforts are made to obtain copies of every law on every subject likely to be legislated upon; books and pamphlets, letters, legal briefs, articles, "clippings" from contemporary sources that contain matter germane to proposed legislation are obtained, arranged, and abstracted. Experts, including university men and men of practical experience, are invited to criticize and comment upon the subjects to be considered.

After the legislative session opens the bureau is eagerly at the disposal of legislators to obtain for them speedily, accurately, and concisely the data that they desire.

Finally the bureau stands ready to draft bills for members.

The growth of this scheme is significant. Beginning at first without legislative authority in 1901, with an allowance of some $1,500, in 1903 a bill was passed authorizing it; in 1905 its appropriation was $4,500; in 1907, $15,000, and at this time, January, 1909, its director, I am informed, has had considerable difficulty in avoiding, owing to the efforts of enthusiastic supporters, an appropriation of $50,000. Last session 90 per cent. of the bills were arranged and drafted in this department. Before this present session had opened 60 per cent. of the legislators had visited the department on missions of inquiry, and although the session has barely begun, the bureau is already working on about fifty bills. Bureaus modeled on this scheme, as it developed in Wisconsin, have been initiated or established in Nebraska, Iowa, California, Indiana, New York, and Michigan.

I have taken space in this report to describe something of the work of this bureau because of its informal but real relation to the university.

The bureau is under the control of the Free Library Commission of Wisconsin, of which the president of the university is an ex-officio member. The director of the bureau, the man to whose genius, skill, and force the whole scheme was due, Dr. Charles McCarthy, was and is lecturer on political science at the university. The chief draftsman is M. S. Dudgeon, an instructor in political science and so on. Much of the investigative

work of the bureau is carried on by university students —mostly graduates—members of Doctor McCarthy's advanced courses, who receive university credits for the work done. An example of such work may be interesting. I visited the bureau one day to find working at a table the instructor of political economy at the university, and two advanced students; they were preparing a bill. The university was making that bill; it did not initiate it, but it was making it painstakingly and with expert knowledge, so that it would stand the strain of its after-enforcement. So it makes, to all intents and purposes, 90 per cent. of the bills that come before the house.

These statements, however, by no means describe the full university relation. I am not only credibly informed, but I am convinced, whatever may be the plans adopted by other States, that this all-important bureau could not possibly exist on its present basis of high efficiency without the university connection. The fact of the matter is that by far the larger part of the knowledge which most concerns present-day legislators can be obtained best and sometimes only from the universities. Our immensely complex civilization demands the solution of problems of which former legislators had no idea—problems legal, medical, chemical, agricultural, hygienic, engineering, political, economical, etc., and it is in the universities that specialists in these subjects work and teach. I should like to show how this works

out in practice. To Doctor McCarthy, director of the bureau and lecturer in political science in the university, there comes some legislator seeking real information on a specific subject. In the director's room there lies instantly at hand a comprehensive index of whatever the great university library contains concerning that subject. If that is not sufficient, at the end of the telephone there lies the whole staff of the university, of which the director knows every man that is a real authority. He instantly communicates with him, and in an hour the man and the information are at hand. If the university man does not know, then he knows the man in some other university that does, and a telegram produces him; it produces not a book, but a *man* who really knows and who talks straight and plain. This is not an occasional happening, but a constant habit. The university continually pays tribute to the State in accurate, comprehensive knowledge.

THE RAILROAD COMMISSION

The recent Wisconsin Public Utilities Law (July 9, 1907) has been pronounced the most complete law providing for the regulation of public service corporations ever enacted. It provides for jurisdiction over companies producing or transmitting light, heat, water, power, and over telephone companies. Its administration was placed in the hands of the Railroad Commission, which already had similar jurisdiction over

steam and electric railroads and all instrumentalities connected with them, as well as over telegraph and express companies. The powers of this commission, still legally termed "The Railroad Commission," are thus unique; they are equaled by the powers of no public utilities commission in this country. The laws under which this commission works place the responsibility for providing reasonably adequate service and of establishing reasonable rates upon the management of the plants and corporations concerned. All rates, rules, regulations, and service of such corporations may be challenged at any time and revised or modified by the commission, either upon complaint of individuals or on the initiative of the commission itself. The duties of the commission are comprehensive.

There has been imposed upon it the duty of valuing all the public utility plants in the State of Wisconsin, taking account of every item of value from a telegraph-pole or trolley-wire to "good-will" and "franchise-value."

It has also laid upon it the duty of prescribing uniform forms of accounts for all the public utilities operating within the State, in order that their books shall be kept in such a way that after the valuation of a specific plant is ascertained its financial condition, from year to year, may be readily and accurately ascertained by the commission. As this system of uniform accounts applies to municipal and private plants alike, a large

amount of exceedingly valuable information is already appearing.

As previously stated, all rates of service are established in the first instance by the companies themselves; they are thus on the defensive, and may be challenged at any time. The commission has been engaged in elucidating the principles upon which just and reasonable rates should be based for all the different utilities, and in accordance with the statement of one of the commissioners, "it expects that in the not distant future all the utilities operating within the State will make their rates in accordance with uniform principles embodying the latest and best that scientific method and scientific thought can contribute."

With regard to "reasonable service," the commission has already put into effect a series of rules regulating with scientific precision and rigidity gas and electric service. Other rules and regulations applicable to the other utilities will be adopted in the future. The rules regulating the gas and electric service prescribe standards for gas pressure, quality of the gas, voltage, care of lamps, lamp renewal, records of complaints, disturbance in the service, etc.; and the full and complete administration of this feature of the commission's work alone will doubtless require a considerable inspectional staff. The results, even now, show conclusively many comprehensive failures to provide anything that could be at all characterized as "reasonable service."

As all orders of the commission are subject to appeal, it is interesting to notice that since the operations of the commission only three railroad decisions have been taken into court, and no utilities decisions whatever. Concerning one of the railroad appeals, an epoch-making decision was handed down by the Supreme Court in the year 1908. After a comprehensive review of the statutes and circumstances concerned, it declares that even though the court might feel that the commission should have rendered an opposite decision, yet, if no errors of law have been committed, and the question is one regarding which reasonable and competent men might differ, the court will not set aside the order of the commission.

The operations of the commission, as outlined above, have already resulted in certain consequences which in the future will doubtless be accentuated. These consequences I shall outline here as they were given to me by one of the commissioners. They thus form an interested statement, though I do not believe it to be an unfair one.

Already it appears that the commission is acting as a clearing-house for information between the public and private plants and municipalities. The commission is not one merely judicial or condemnatory in its character, but one essentially helpful. Owing to the high efficiency of its engineering staff it can be and has been of great utility as a sympathetic advisory board

for the plants under its jurisdiction—its collected information goes not only from one plant to all others, but to the people, and often obviates the necessity of making complaints.

This Wisconsin legislation has taken the utilities as well as the railroads out of politics. There seems to be a universal consent to the statement that neither in the primary campaign, nor in the campaign preceding the last November elections, did the utilities as such enter into politics. What this means to good government is wholly obvious.

The Utilities law tends to eliminate feuds between the citizens and the managements of public and private plants. The law assures to all communities good service at reasonable rates—and the bases of the findings of the commission are published to all alike. These published findings should and do suffice to convince the average citizen of the reasonableness of the decision; but whether the citizen likes it or not he *must* abide by that decision.

It raises the standard of morality by eradicating the evil of discriminations in rates—an evil so immense, I am informed, as to be almost beyond comprehension. The whole State of Wisconsin was streaked and plastered with discriminations on the rates of utilities. As it is now all rates, rules, and regulations in effect in the State are on file with the commission, and these are the only rates and regulations that can be lawfully enforced

and collected. Free and reduced service has been absolutely prohibited.

As it has done away with unjust discriminations, so it has done away with unbusiness-like methods in plant management. The commission discovered that many plants were not being operated on a business basis at all, and that a good many of the managements did not have the remotest idea as to the exact standing, from a business point of view, of the plant they were operating. Now, uniform accounting and rules governing the regulation of rates and of service compel the adoption of business and scientific methods.

As a concluding result of the operations of this law and its administration, it ought to be pointed out that its effects are bound to place investments in public utility corporations on a more stable foundation, to remove them generally, if not entirely, from the field of speculation, and to place them in the class of conservative, certain, and stable investments.

I have referred in this slightly detailed way to the operations of the Wisconsin Utilities Law in order, at this place, to point out the university relation. I wish to show that the administration of this law, on its present acknowledged high plane of efficiency, would have been absolutely impossible without the university connection. Even the formulation of the law, as the formidable instrument it is, would have been impossible without this university aid, for it was prepared in the Bureau of

Legislative Reference, which, as I have shown above, is in large measure virtually a branch of the university, and to this bureau in a consultative capacity were summoned many university men, real experts in the matters concerned. Notably in this connection there ought to be mentioned Professor Commons, of the Department of Political Science.

As the next step in the university relation, we find that the chairman of the Railroad Commission, under which this law operates, was and is a lecturer in the department of political science at the university, Mr. B. H. Meyer, a man known throughout the State as one of its strongest administrators. I have been assured that the commission has made and will make free use of the advisory and consultative aid which the university has so often proven its power to bestow.

But the administration of this law does not depend alone upon trained jurists and students of political economy. The law would be utterly hopeless of administration without the aid of a strong engineering staff. This staff, which is unquestionably the strongest and most capable band of men ever gathered together for such a purpose, works equally for the Railroad Commission and the Tax Commission. I have been frequently and authoritatively told not merely of the high efficiency with which this engineering staff carries out its delicate and difficult functions, but as well of this, that on a practical basis it simply would not have

been possible to have gathered in this efficiency except through the engineering staff of the university to draw upon both for men and advice.

While the personnel of the staff is constantly changing, it may be significant in this connection to insert the following statement of Professor Pence, the engineer in charge:

STATEMENT RELATIVE TO THE ENGINEERING STAFF OF THE RAILROAD COMMISSION OF WISCONSIN (THE MAJOR PORTION OF THE SAME STAFF ALSO ENGAGED IN VALUATION WORK FOR THE WISCONSIN TAX COMMISSION).

1. Members of the engineering staff who are also members of the teaching staff of the college of engineering of the University of Wisconsin.

PERSONS REGULARLY ENGAGED ON STAFF:

Engineer in Charge......*Professor of Railway Engineering.*
Chief Mechanical Inspector....*Professor of Machine Design.*
Expert on Light and Heat..*Professor of Electro-Chemistry.*
Field Mechanical Inspector.*Assistant Professor of Machine Design.*
Assistant Field Inspector........*Instructor in Machine Design.*
2 Engineering Computers..*Instructors in Railway Engineering.*

PERSONS ENGAGED IN OCCASIONAL SERVICE ON THE COMMISSIONS' ENGINEERING STAFF

3 Assistant Inspectors of Gas and Electric Service.
Instructors in the Departments of Electrical Engineering and Electro-Chemical Engineering.

2 Expert Inspectors of Bridges .... *Instructors in Structural Engineering.*	
Number of university faculty on regular engineering staff..	7
Number engaged in occasional service	5
Total	12

Of those staff members engaged in investigations of technical matters for the Railroad Commission 68 per cent. are graduates of the University of Wisconsin; 94 per cent. of the entire technical staff are university graduates; our men are, with two exceptions, all college graduates.

The present technical staff includes thirty-five engineers and technical assistants and five stenographers.

W. D. Pence, *Engineer.*

That the University of Wisconsin has been materially concerned with the operation of the Utilities Law is thus evident enough, but it is all enforced by the additional fact that the laboratories of this commission are situated in the Chemical Engineering Building of the university, and that as a matter of fact they are joint laboratories. There the interesting work on the gas and electric standards has been carried out by the university members of the commission, and in this place will be carried out the future testing operations of the commission in all the various fields over which it has jurisdiction. Mention ought also to be made of the fact that recently arrangements have been made with the Hygienic Laboratory of the State, also situated in the university, for the examination of the water supplies in which the commission is interested.

The Legislative Reference Library and the Railroad

Commission constitute the two most salient examples of governmental dependence upon the university. The fact of this dependence is, however, general through the departments in the Capitol.

THE STATE TAX COMMISSION

This commission, formed under the law of June 15, 1905, in common with the Railroad Commission, employs the services of the engineering staff discussed above. But outside of this its dependence upon the university has been marked. Particularly is this the case in the services rendered by Dr. T. S. Adams, professor of political economy at the university. Every one with whom I conferred on this subject expressed the highest appreciation of Professor Adams' services in this connection. Then, too, many and valuable services have been rendered from time to time by graduate students working out, as university researchers, certain problems with which the commission was confronted. In several instances, I am informed, they succeeded in demonstrating the falsity of certain principles upon which other tax commissions had proceeded. In conversation with one of the commissioners, he stated emphatically that the commissioners did not find that university men were theorists "with their heads in the air," but, on the contrary, were men of practical sense, of wide information—that the commission could not possibly have succeeded without them, and that as they

had called them in the past, so they expected to summon them in the future.

The Labor Bureau is in a similar position. This bureau is not nominated or controlled in any way by trade-unions or labor organizations, but is a regular department of the State, impartial, but with sympathies toward labor. It is in large measure indebted to the university. Prof. J. R. Commons, "whose skill as an investigator is an inspiration to those who work with him," has rendered "invaluable assistance." Most of all, however, it is indebted to M. O. Lorenz, assistant professor of political economy. Professor Lorenz, as a matter of fact, was given a year's leave of absence from the university and loaned to the State as Deputy Commissioner of Labor. This impels me to remark that the university frequently does this, and, on the statement of the president, "is glad to do it"—*i. e.*, to lend men to the State "on leave of absence."

The last work of Professor Lorenz, and one that shows his eminent ability as a statistician, is a report on "Industrial Accidents and Employers' Liability in Wisconsin." This published report constitutes a mass of anticipatory material for the legislation on this subject proposed for the present session.

THE DAIRY AND FOOD COMMISSION

This branch of government, like our own in so far as the chemical end of it is concerned, is in the hands of

the university; it has charge of food, drugs, dairy products, and linseed oil, etc. But unlike our own, it is in the hands of one man. This man is Dr. R. Fischer, assistant professor of pharmacy at the university. Doctor Fischer receives the salary of head chemist of the commission and, in addition, one-half his university salary; he devotes about one-half his time to the work of the commission and the full time of three assistants. His laboratories, which are at the university, receive some nine thousand dollars for their up-keep, the total yearly expenses of the commission being about fifty thousand dollars. The total number of prosecutions per year is about two hundred, a large number considering Doctor Fischer's reputation, which is that of a man absolutely incorruptible, of immense courage, and of bulldog tenacity; his name, I am informed, is a word of terror to adulterators throughout the State.

COMMISSION OF THE GEOLOGICAL AND NATIONAL HISTORY SURVEY

The relation of this survey to the university may be expressed as follows:

BOARD OF COMMISSIONERS

The president of the commission is the president of the university.

The vice-president is a regent of the university.

The secretary is the director of the chemical department of the university staff.

STAFF

The director of the survey is the dean of the College of Letters and Science of the university.

One biologist of the survey is a lecturer in the university, and another is an assistant professor.

One chemist of the survey is a professor of chemistry at the university, and another is an instructor.

The chief of the lighting division is an instructor at the university, and the engineer in charge of water power is professor of civil engineering.

This taken in connection with the fact that the laboratories of the survey are at the university, the survey becomes to all intents and purposes a department of the university.

The work of this survey thus becomes significant as university work. Of course much of this work is purely scientific in its nature, but much, again, is highly utilitarian. Most important in the utilitarian work is that involving highways, roads, and bridges. The direction of this work was undertaken by Prof. W. O. Hotchkiss, of the university. His report on the "Rural Highways of Wisconsin" was widely distributed and stirred up public opinion on the subject of good roads to such an extent that in 1907 the Legislature made a special appropriation to cover the expense of such a work on the

part of the survey. The work undertaken by the survey has been advisory and demonstrational. In an advisory capacity it has visited on request sixty-three localities in thirty different counties. In demonstrational work the highway division has taken actual charge of the construction of roads built with local funds, in order to show the best methods to use, and this to quite an extent. Surveys have been made for laying out new roads and for cutting down hills.

A similar educational and demonstrational work has also been undertaken in the case of bridge-building. The survey has already inspected, surveyed, and furnished plans for one hundred and twenty bridge-sites in thirty-three counties. The most important, however, of all the work is educational. The brief pamphlets prepared by the survey have interested the people in the State on the subject, and requests for these pamphlets on the part of other States have widely extended the influence of this crusading work.

Another important utilitarian work undertaken by the survey in association with the university is a comprehensive examination of the soils of the State. Still another is an examination into the water powers of the State in behalf of the commission on conservation.

An interesting and important investigation taken up by the survey has to do with the study of lakes, and it has already resulted, particularly on account of the work of Prof. V. Lenher, of the university, in valuable

contributions concerning the conditions of fish life in these lakes. The survey is interested in other researches, with useful features, but sufficient has been said to indicate the comprehensive nature of the university influence.

The Fish Commission, more or less allied with the survey, has as one of its commissioners, *by law*, the professor of biology of the university.

The State Hygienic Laboratory has relations with the university similar to that of the laboratory of the Dairy and Food Commission. The laboratory itself is situated in the university, and its director is Dr. M. P. Ravenel, the professor of bacteriology in the university. This laboratory, whose university connection is thus sufficiently obvious, is concerned mainly with the prevention of disease. Its main function is the examination for any person in the State, by application through any health officer, of any material—water, urine, pus, etc.—suspected to contain contagious matter of typhoid fever, tuberculosis, etc. Its utility in this regard is so highly appreciated in the State that it may be best expressed in the words of the president of the university: "If I were dictator of this State, in ten years I could utterly wipe out typhoid fever and tuberculosis." A recent activity on the part of this department is an arrangement with the extension department of the university by which they have unitedly started in with an anti-tuberculosis crusade, the proposed extent of which will

be afterward referred to. A still more recent activity is a somewhat similar arrangement with the engineering staff of the Railroad Commission, by which industrial analyses will be made of the waters of the State, and for manufacturing purposes.

Still other university relations are to be found in other departments of government, such as the Free Library Commission, the Fish Commission, the Park Commission, the Conservation Commission, the Board of Teachers' Examiners, etc.

The relations of the university to the State that I have so far discussed are the relations of the men on the staff of the university to the government.

Quite apart from these relations there are others which the university bears to the people themselves.

UNIVERSITY EXTENSION

In order to understand the scope of this movement in the University of Wisconsin, attention ought to be directed to the ideal of the university as expressed at the beginning of this report. The university has been compared to a three-legged stool, of which one leg stands for "teaching at Madison," the second for "research," and the third for "extension." If the university, then, is to stand firm and strong, it is necessary that the extension phase of its work should be developed equally with its other functions; and it is. It is only by understanding that the University of Wisconsin takes its

triple ideal, positively and truly, with absolute seriousness that we can understand the logic of the huge development of this extensional scheme. "The university an instrument in the upbuilding of the State," "in ways as broad as human endeavor and as high as human aspiration," is the living faith of Wisconsin.

The extension division of the university is under the control of a director and a large corps of assistants. Its work has been divided into four departments.

(1) Correspondence study.

(2) Instruction by lectures.

(3) Debating and public discussion.

(4) General information and welfare.

DEPARTMENT I OF THE DIVISION OF EXTENSION

CORRESPONDENCE STUDY

In connection with the initiation of this department of study, it was discovered that from eight hundred thousand to one million dollars a year went out of the State to commercial correspondence schools throughout the country, and that in the State there were no less than thirty-five thousand young men pursuing such studies. The correspondence schools of the country were obviously fulfilling a need for pecuniary considerations that it was incumbent upon the university to fulfil for the good of the State.

In its methods this department conducts its corres-

pondence work just as do the commercial correspondence schools—*i. e.*, through the ordinary routine of lessons by mail, replies and corrections. As a supplementary feature, however, it provides instructors who meet classes of these students throughout the State. The fee which it has been found necessary to charge students is twenty dollars for a five unit-hour study—the equivalent of over one hundred dollars a year tuition at the university. The number of instructors giving correspondence courses is at present seventy-four. Most of these instructors are regular teachers at the university, but the department is already employing instructors who give their whole time to correspondence work. Though it was so short a time ago as November 1, 1906, that the first student was registered, there were already entered in the correspondence school fifteen hundred and four students December 1, 1908, and the number is growing at the rate of about one hundred and fifty per month.

Students pursuing these courses may take:

(1) Regular university grade work, for which, under certain conditions, university credits are given.

(2) Special advanced work for graduate students.

(3) High-school and preparatory work.

(4) Elementary school branches.

(5) Special vocational studies.

Among the students enrolled are to be found laborers, apprentices, farmers, traveling men, skilled mechanics, salesmen, clerks, stenographers, bankers, business men,

home-makers, club-women, students, teachers, lawyers, clergymen, doctors, and civil officials. An immensely preponderant number of those entered for the foregoing courses are pursuing vocational studies.

INDUSTRIAL INSTRUCTION BY CORRESPONDENCE

This phase of the work has met a remarkable appreciation from employers and employees alike. Owing to the fact that this work has grown with such an acceleration, the funds at the disposal of the department were wholly unable to meet the demand, and it was found necessary, during the past year, to limit industrial instruction practically to Milwaukee. The success of the scheme as applied to this city has been remarkable. Various manufacturing concerns have allowed time for class purposes without lapse of pay; they have provided for their employees class-rooms, properly equipped at the company's expense, in which to meet the instructor. In certain cases, through an arrangement between the men and their employers, the students' fees are paid by the firm direct to the extension division. In one instance wages were raised in order to enable the men to afford the cost of a correspondence course; in another the fees of the apprentices were paid by the company. But if the attitude of the employers has been appreciative, the attitude of the men has been equally so. I have heard stories, remarkable and pathetic, of the appreciation shown through devotion to study, of the men enrolled

in these courses; and the results they have achieved have been beyond the most sanguine expectation.

Concerning the value to the State of the vocationally trained man, it has been calculated that for every man the correspondence school so trains the wealth of the State is increased $8,000.

The university has so far touched but the edge of this immense field. There are in Milwaukee alone 54,000 men employed in the larger concerns alone, while in the whole State of Wisconsin the number of men employed by manufacturing firms aggregates 250,000; it is obvious, then, that by multiplying 250,000 by 8,000 the resulting number will give more or less an approximation of the increased value to the State could the university reach its every man.

To such a degree is this industrial correspondence appreciated in Milwaukee that within the last week the representatives of the Merchants and Manufacturers' Association of Milwaukee, the strongest oganization in Milwaukee, visited the Governor and, in behalf of the association, urged that the appropriation for the extension division of the university should be increased 50 per cent. beyond its asking; it is not surprising, then, to learn, as the result of this experiment in vocational training by correspondence, that the university has rented a house in Milwaukee which it proposes to fit up with laboratory and class-rooms for instructional purposes; nor that it proposes to send about the country

traveling laboratory outfits for such purposes; nor that it now purposes, in connection with the engineering subjects, to set aside in the engineering buildings of the university a laboratory for correspondence students.

Certain features of this correspondence work are interesting. Courses have been given, for example, in "business administration"; in "home economics"; in "highway construction" for supervisors, out of whom one hundred and seventy took a course concerning the business of expert road-making. One little example of the way in which this correspondence department fits into the needs of the people was brought incidentally to my knowledge. There is in Milwaukee a branch of the National Association of Bank Clerks. This society has been holding bi-weekly meetings for self-improvement, paying members of the Milwaukee Law School ten dollars a night for lectures. From thirty to forty members of the society were always in faithful attendance. Now, under the ægis of the correspondence department, this whole business of the self-improvement of bank clerks has been taken over by the university with an immense gain in results and a lessening in cost to the members of the society.

The correspondence department now proposes to extend its activities to State institutions, such as prisons, reformatories, etc.

Concerning this correspondence department of the extension division, it ought to be said, in conclusion,

that its students are a select class. It may be that they are poor boys of ability who thus gain an opportunity to develop special talents, or men of family who were married before they recognized their own abilities, or men who through starting wrong have got into unsuitable occupations—in general, men who, deprived of early opportunities, desire to prepare themselves for fitting positions in which they may realize more nearly what they are capable of. They may be business men seeking instruction in organization and administration, or they may be housekeepers or home-makers interested in better cooking and sanitary living. They may be teachers, doctors, clergymen, men who may be well educated, but who wish to progress. Most decidedly, they are a seleot class, and mean "business." In view of the enormous extension of the correspondence schools of America it is evident that they actually do provide opportunities for help and inspiration, and hence it appears that the university, standing as a people's university, and not as an aristocratic organization, is absolutely justified in entering this field.

DEPARTMENT II OF THE DIVISION OF EXTENSION

INSTRUCTION BY LECTURES

This branch of extension work is to be found in many universities, and it is generally moribund. The reason for this seems to rest on the consideration that on the

inception of this extension lecture-work it is entered upon by some of the best men on the staff, and that their lectures are so acceptable that the demands made upon their time become onerous and that they subsequently find it necessary wholly to abandon them. The consequence of this is that such lectures become ever more and more relegated to inferior men, or at any rate to men the acceptability of whom does not render their extension work onerous, and that ultimately the whole scheme becomes "queered" in the minds of the people.

Now, the University of Wisconsin realizes perfectly that the work of extension lecturers has possibilities second to no other, that such messages of up-lift, of information, of inspiration, and of direction are a wonderful force for good in the State; but it also realizes that the number of men on the staff of a university capable of uttering these messages with inspirational power and truth are very, very few. The fact of the matter is that the qualifications for such work demand very peculiar gifts. The university, however, purposes to search for such men throughout the country, to place them permanently on the staff of the university, and to see to it that they have no divided interests. While it is intended that such men may engage in residence work at the university for short periods in order to keep in touch with it, the main current of their energy and thought is to flow to the outside problem. It is purposed by the university to spend at least one hundred

thousand dollars a year for this department of university extension alone.

DEPARTMENT III OF THE DIVISION OF EXTENSION

DEBATING AND PUBLIC DISCUSSION

This remarkable department concerns itself with the business of creating or fostering public interest for the social and political questions of the day. This it does by assisting in the formation of debating societies, and by collecting and classifying reference material in the shape of newspaper and magazine articles, books, and State and National publications, which as a loan collection passes from the department to civic leagues, town councils, library and school boards, farmers' and business men's clubs, high-school and academy societies, and such like organizations over the State. The department also compiles, publishes, and distributes on a wide scale bulletins formulating subjects for debate and containing full lists of references on both sides of the question. Good use is made of this form of the department's activity by pupils in the high-schools, who now no longer debate as to whether "the country is preferable to the town," etc., but, on the contrary, are concerned with vital current questions. Among these interesting debating pamphlets I notice "Popular Elections of Senators," "Immigration," "Initiative and Referendum," "Guaranty of Bank Deposits," "Poetry and

Prose Fiction," "The Recall," "The Parcels Post," "Commission Plan of City Government," "Woman Suffrage," "Proportional Representation," etc. Among the informational pamphlets outside of debating I notice "Municipal Home Rule Charters," "Interchange of Service," etc.

The department makes free use of all the other departments of the university for material, and also of the Free Library Commission, and of the Legislative Reference Library. In fact, it is the aim of the department to do for the men who elect the Legislature just what the Legislative Reference Library is doing for the legislators themselves.

During the last university year some three thousand people in various organizations were materially aided in the State, and there has been a wide request for the department's debating and informational bulletins from the people of other States.

DEPARTMENT IV OF THE DIVISION OF EXTENSION

GENERAL INFORMATION AND WELFARE

Quite aside from the departments of the extension division already considered, there is another concerned with "General Information and Welfare." This department has as its specific work the duty of acting as a medium between the great Federal and State departments, national societies, and State universities on the

one hand, and the people of the State on the other, in disseminating in a way to be understood of the people the results of investigation and research. It is bringing before the people in a way they can grasp and utilize the latest facts concerning food, hygiene, natural resources, agricultural and dairy processes, household interests, engineering and manufacturing conditions, etc.; discoveries affecting the prevention and care of disease; labor questions; child study; garbage disposal; dust and smoke prevention, and many others concerning the social, educational, and political environment of the individual. This department proposes, positively and seriously, to gather the stores of contemporary information of the expert, and to republish them in simple and practical form; and it is actually doing it. The department is glad to ally itself with other associations. Thus in connection with the Anti-Tuberculosis League and the State Sanitary Board it has entered into a crusade against tuberculosis. The extent of its plans in this regard is remarkable. It is proposed to employ a railroad car for the purpose of holding a tuberculosis exhibit, to retain the services of a man of high scientific attainments and demonstrational power as a lecturer, and then to visit systematically every town and village in the State; it proposes to supplement this work by pamphlets and bulletins sent broadcast, and as a result it expects to drive home and hammer down a knowledge in every individual in the State as to the


THE UNIVERSITY OF WISCONSIN
THE EXTENSION DIVISION
MAP
OF
WISCONSIN
SHOWING
STATE DIVIDED INTO DISTRICTS
LEGEND
SEAT OF UNIVERSITY
DISTRICT CITY
CITY OF 4500 TO 20000 INHABITANTS
" 2500 - 4500
" 1500 - 2500
" 1000 - 1500
SCALE - 1 INCH = 10 MILES
DOUGLAS
BAYFIELD
ASHLAND
IRON
VILAS
BURNETT
WASHBURN
SAWYER
FLORENCE
FOREST
ONEIDA
PRICE
POLK
BARRON
RUSK
MARINETTE
LINCOLN
LANGLADE
TAYLOR
OCONTO
ST CROIX
CHIPPEWA
DUNN
MARATHON
SHAWANO
PIERCE
PEPIN
CLARK
DOOR
BUFFALO
WOOD
WAUPACA
OUTAGAMIE
BROWN
KEWAUNEE
JACKSON
PORTAGE
TREMPEALEAU
MANITOWOC
WAUSHARA
WINNEBAGO
CALUMET
LA CROSSE
MONROE
ADAMS
JUNEAU
MARQUETTE
GREEN LAKE
FON DU LAC
SHEBOYGAN
VERNON
COLUMBIA
RICHLAND
SAUK
DODGE
CRAWFORD
WASHINGTON
OZAUKEE
IOWA
DANE
JEFFERSON
WAUKESHA
MILWAUKEE
GRANT
LA FAYETTE
GREEN
ROCK
WALWORTH
RACINE
KENOSHA
ASHLAND
EAU CLAIRE
WAUSAU
STEVENS POINT
GREEN BAY
OSHKOSH
MADISON
RICE LAKE
LA CROSSE
PLATTEVILLE

proper methods for the prevention and treatment of tuberculosis. The department proposes in due course to pursue the same methods with regard to typhoid fever and other contagious diseases. The faith of the president of the university in this plan is shown in his statement concerning contagious diseases already referred to. Another instance of helpfulness appears concerning the Association of Stationary Engineers. This association publicly thanked at Denver this department of the extension division of the university for the help afforded its members. Another instance of helpfulness is found in the establishment in Milwaukee of a Baker's Institute under the control of this department. It was established at the request of the National Association of Master Bakers, and is already exciting the attention of the baker's trade throughout the whole country.

In order to co-ordinate the activities of the whole extension division of the university, a field organization is planned which will carry the benefits of the scheme to every hamlet in the country. In accordance with this scheme the whole State is divided up into districts, each one of which will be under the control of a permanent resident representative, with stationary headquarters. As illustrative of this scheme, I inclose herewith a diagram which has just been drawn by the division, and for which I am indebted to the courtesy of the director. At the various centers indicated in the

diagram arrangements will be made for lecture courses, correspondence courses, special exhibits and demonstrations, consultations on topics relating to local interests, etc. The headquarters in each center will also co-operate helpfully with town councils, school boards, library boards, etc., and will as well act in an advisory capacity for boys and girls in the selection of their life-work.

The needs of the extension division are best exemplified in its plans for the coming year. Thanks to the courtesy of the director of the division, I am enabled to add below the whole scheme, together with its cost in detail.

It will be noticed that the division of extension proposes to spend $248,650 a year. This they will be enabled to do on the basis of the $100,000 a year requested from the State, $50,000 in fees going into the division, and the residue from other university and State services.

In connection with the importance of this whole division to the university and the State, it is significant to say that a short time ago certain reactionaries in the Legislature proposed to "investigate" the university for political purposes; so soon as the purpose became known representatives of the labor unions and trade organizations of the State personally called upon the Governor and informed him that "labor was back of the university in all it wanted to do"; the "investigation" was dropped instanter.

UNIVERSITY OF WISCONSIN AND THE STATE

THE AGRICULTURAL DEPARTMENT

The agricultural department of the University of Wisconsin is almost as extensional in its nature as the division of extension itself. I shall refer briefly to the work of this department in order to make significant the reasons by which it has been able to accomplish so much.

The extensional spirit of the Agricultural Department has been shown ever since 1889, when it established the short course. This course, consisting of fourteen weeks in the winter for two years, and requiring no matriculation qualifications, has been of fundamental importance in determining the attitude of the farming community toward the university; it has been enormously valuable. The graduates of the course form a great association spreading over the State, the members of which are always cordially receptive to the experiments which the department wishes to carry out and to the suggestions it conveys. The yearly number in this course now averages about six hundred. A still shorter course has been established of ten days' duration in the summer, and the demonstrational work carried out during this time before the one thousand adult members of the course has been of enormous value to the university.

What the Agricultural Department has accomplished for the farmers of Wisconsin through its researches, its demonstrations, and its teachings it would take many

pages even to synopsize. In increasing the yield of corn per acre, in ridding the State of scrub barley, in increasing the yield of potatoes, in improving the grade of tobacco grown in the State, in attacking bovine tuberculosis with such energy and efficiency that it is on its way to extermination, etc.—the list could be carried on and on and on up to any desirable stopping place to justify the Governor's statement made to me on leaving Wisconsin: "The Agricultural Department has already added more money to the State than the whole university could spend in fifty years."

The important point in connection with this report is not so much what the Agricultural Department has done, but, rather, how it has done it. How has it accomplished results so huge as to make the achievements of the average agricultural college appear almost insignificant in comparison?

The answer interested me because of the fact that in the University of Kansas we have no Agricultural Department. I inquired persistently in the Agricultural Department and through the university at large from high officials and petty instructors. The answer was always the same, freely given and without proviso:

It is because of the university connection.

The reasons for this, obtained from different sources, appear to be as follows:

(1) Being freed from instructional duties in general subjects, such as chemistry, physics, English, etc., the

department has been able to devote itself exclusively and intensively to teaching and research in agriculture.

(2) The funds which would have been required for general instruction they have been able to devote to increased equipment and staff for purely agricultural purposes; in addition, the university connections have admitted of "a division of labor" which has been profitable to the Agricultural Department both from the standpoint of efficiency and economy.

(3) Owing to the university connection, the Agricultural Department has been saved from the error of going into the development of engineering courses such as have been indulged in by various agricultural colleges, and which would have distracted them from the development of their sole business—*viz.*, agriculture.

(4) The grade of instructional ability, both in the Agricultural Department and, for the general courses, in the university outside, has been very much higher because of the university connection; in addition to this, the grade of research ability within the department is much higher because of this university connection; in a word, they can obtain men for instructors and researchers because the department is a part of the university that they never could obtain were it otherwise.

(5) Because of its university connection, the department can train students in its four years' course as it never could hope to do were the department separate from the university; the university with its vast and

efficient laboratories provides an efficient training in the pure sciences upon which the real science of agriculture depends. Four years in the agricultural department of the university could not possibly be approached by four years in an agricultural college with no university association.

(6) The university spirit—the spirit of culture—and the university environment, with all its inspiring influences, has been of the most practical kind of value to the Agricultural Department, in students and staff alike.

(7) The influence of the university over the whole people of the State has been of unquestionable value in obtaining for the more sectional needs of the Agricultural Department satisfying appropriations.

Perhaps the whole matter may be best summed up in the statement of the dean of the department, that even though the department, were it separated from the university, could obtain vastly increased appropriations (which it could not), it would still cling to the university.

But the converse of all this is equally true: The Agricultural Department is equally valuable to the university. I inquired, as I have said, persistently, and it is no mistake to say that there is a unanimity of conviction throughout the whole university as to the advantages derived through the presence of the Agricultural Department within it. The fact is, it is mutually not merely an advantage, but it is, in so

far as good functioning goes, a necessity. This may be inferred from the statement of the president, who, referring to our own divided administration in this regard, said: "Better to burn down the Agricultural College than to inflict upon future generations the evils of a divided administration and the loss of the benefits which arise from centralization," or from the regret expressed by the Governor of Wisconsin, who, after inquiring as to the relation of the Agricultural College to the University in Kansas, said, emphatically, that it was most unfortunate that the two institutions had ever been divided.

THE COLLEGE OF ENGINEERING

This large and important department of the university, despite the strain to which it has been subjected through its rapid growth, has found time and place for both extensional work and work of practical value for the people of the State. Thus, it has established a summer school for artisans, and during the summer as well offers advanced instruction in certain technical studies. It has also done a large amount of work for the State in its relation to the Railroad and Tax commissions, as described in the first part of this report.

Its graduate and research work is particularly notable for its practical value, and the university bulletins publishing this work have been in demand in other States. A recent research of great value, and significant

as illustrating the wide views of the university, inasmuch as it has been carried out gratuitously by the university for railroad corporations, concerns the study of the effect of moving trains on railroad bridges. Several instructors have been employed in this work for two summers.

THE SCHOOL OF COMMERCE

The formation of this school, in 1900, illustrates the breadth of view of the university and its readiness to break with academic traditions when afforded adequate reason. It was founded in order to fill a need on the part of business for educated trained men in accounting, banking, the consular service, etc., and on the part of young men to obtain such a training. The need was apparent from the following considerations:

(1) The high-schools were not sending their best material to the university.

(2) Many students were entering engineering and law not in order to practise the professions, but simply as a preparation for business.

(3) The class of special students was a growing class and composed in large measure of men who proposed to enter business, and who did not find in any one department what they needed.

Since the establishment of the course 60 to 70 per cent. of its students have stated that but for it they would not be in the university at all. The num-

ber of special students has decreased. As a matter of fact, the constituency of the school is practically a net increase to the number of the regular students in the university. The regular students in the school number about two hundred and thirty, of which 20 per cent. come from other States. Concerning the thoroughness of the course, the "mortality" is higher than in any other course in the university, and two hours a week more are required from its students. The success of the school is so great that from various business houses it receives five times as many applications for its graduates as the school can supply. It has furnished five teachers to universities. Finally, it ought to be said that the school finds it necessary to give at the end of the freshman year, when the regular students enter its own proper studies, special examinations in English and arithmetic, owing to the fact that 75 per cent. of regular university students entering the course can neither write a decent letter nor add a column of figures.

INCIDENTAL RESEARCHES

Altogether apart from the direct aid extended by members of the staff of the university to the State and by university departments to the State, there is a vast number of researches carried out by the members of the university which collectively constitute a magnificent showing of what can be done by a people's university

for the increase of knowledge. The mere enumeration of these researches would transcend the spatial limits of this report. It may be in the engineering department, where men are investigating the electrolytic corrosion of boilers or devising a meter for measuring steam; or in the chemical department, with its investigations into osmosis or rare earths; or in the physics department, with its method of thawing out the frozen water-pipes of a city system; or in the English department, where a member of the staff has written a good play, which is to be produced in Washington (greatly to the joy of the university); everywhere there is the creative spirit. The reason for this is that in accordance with the living faith of the institution every man *must* do something, and that something must be creative, not merely critical; promotion depends on it, and the respect of his colleagues.

UNIVERSITY PUBLICATIONS

In order that this manifold research activity should be properly and promptly presented, distributed, and utilized, the university has taken over from the State Printer the duty of publication. Under the responsibility of a university editor, the university publishes in separate series all research material. While each series of publications is important, and may in one issue run up to many thousands, particular attention may be called to the engineering series of the bulletin, which

has met an immense demand from the whole engineering world.

This report is not intended as a comprehensive expression of what the university does for the State. It is impossible to estimate what it does; the expositions I have given are mere cross-sections of its activities. All that can be said is that it has transformed the State, materially, intellectually, and morally; it *is* the State in the sense that it is the visible expression of the aspirations of the people. The achievements that have resulted through the university and State co-operation may be deemed socialistic; it may be that they are, but they are as inevitable as the fact is true that the people have discovered that they can accomplish collectively what they could not do individually.

At the conclusion of this report the question may be asked as to how the university has been permitted to develop to its present immense strength and efficiency. Briefly, it may be stated that it is due to the spirit of the people of the State. The people of Wisconsin are a conservative people, but they are a thinking people, and since the university has always been able to show that for every dollar it took from the State it returned many, even in material value, the people have appreciated it and supported it. The University of Wisconsin is not the growth of a day, but of a long period of time, and steadily with its growth there has grown a mutuality between the people and it.

The attitude of the State toward the university is best expressed in the words of the Governor, who, when I asked him formally whether "he approved of the present activities and claims of the university," said briefly but emphatically, "I certainly do." As the university is frankly and openly proceeding in its claims on the supposition that inside of thirty years it will have ten thousand students, these words are significant.

Finally, in rendering this report I feel that by laying such stress on the material aspects of its utility to the State I may have misrepresented the university. If, on the basis of this report, it is imagined that the University of Wisconsin is mainly interested in material gain, this report would certainly be a gross misrepresentation. At its seat in Madison it instructs over four thousand students in almost every phase of human thought and endeavor, and in a fashion to give it a legitimate pride. No department in this university would say for an instant that, however apart was its work from utilitarian consideration, it was not properly supported and sympathized with. But, unlike most of the endowed universities, it is not aristocratic; it does not regard education as a possession fit only for the privileged classes. Frankly, and, on the basis of its achievements, convincingly, its purpose is to uplift the people of the State and, in so far as may be, the people of the nation, spiritually, intellectually, and

materially. It is utilitarian only in the sense that it is a *people's* university.

Respectfully submitted,

ROBERT KENNEDY DUNCAN.

To FRANK STRONG, Esq.,
Chancellor of the University of Kansas,
January 18, 1909.

XI

PROGRESS IN INDUSTRIAL FELLOWSHIPS

IN the *North American Review* for May, 1907, and, subsequently, as the last chapter in a book called *The Chemistry of Commerce* (Harpers), the writer published the details of a unique scheme of industrial fellowships which he was initiating at the University of Kansas. Four years have now elapsed, and since nine hundred and ninety-nine innovations fail for one that succeeds, it is natural, and, indeed, important, that he should publish as the last chapter of this succeeding book the progress and present-day status of the scheme.

The scheme itself depends for its value and for its acceptance upon a mutually advantageous arrangement between manufacturing companies on the one hand and the university on the other for the adequate solution of important manufacturing problems.

The present condition of American manufacture is one of inefficiency. Every informed manufacturer today (and most uninformed) knows that he has problems of serious moment, problems so important that in the conditions that obtain *today* their lack of solution means imminent loss for his individual instance of the

industry. It may be safely said that wherever there is the smoke of a factory chimney there are serious problems. To such an extent is this true that any intelligent chemist might very cheerfully accept a wager to go into any factory, and inside of three days point out problems whose reasonable solution would make large differences in the dividends of the company; it is not said that he could solve these problems, but rather that they can be solved by the chemist, and the chemist alone. Many a story might be told illustrative of the amateurishness which pervades American manufacture, as differentiated from its expert office management.

The reasons for this inefficiency as it appears in waste and in the lack of progressive factory practice are clear and definite. Speaking with whatever truth there may be in generalities, the manufacturers of the past have been men not educated in the knowledge of the schools, but men who knew practically nothing of applied science and who, in consequence, forced their way to success through sheer fighting manhood and through the application of principles which they *did* understand.

First among these principles of success was the creation of a tariff. This discussion is not concerned with the question as to whether the tariff is good or evil, but only with the efficiency of American manufacture. It may safely be said, though, that it is not to be expected that a scheme so universal in its scope could be *all* good, and among the faults of its qualities there unquestion-

ably lies the fact that it has injured the efficiency of American manufacture by shutting out the competition of the efficiency of foreign manufacture working through the application of modern knowledge. It has hidden the importance of, and, indeed, masked, the very presence of waste and non-progressive factory practice. To the difference between the cost of labor at home and abroad there has been added, among other things, the difference between scientific efficiency at home and abroad. To the truth of this allegation the procession of men which filed before the Committee on Ways and Means bears ample testimony when in instance after instance the manufacturer, either consciously or unconsciously, claimed protection because of the waste and non-progressive character of his specific instance of the industry.

Furthermore, many American manufacturers found it possible to rid themselves of the necessity of efficiency through the creation of combinations for the elimination of competition.

Combined with these two methods of making financial progress at the expense of efficiency, there were, as well, large stores of raw materials everywhere at hand, and the needs of a rapidly expanding and rather extravagant population which would swallow anything presented to it.

Because of these reasons American manufacture flourished.

Now, however, conditions are rapidly changing. The tariff on its present high pinnacle lies in an unstable equilibrium, and every sensible man knows it. Combinations for the elimination of competition are now illegal and ever more and more dangerous. The vast stores of raw material are now segregated into the holdings of a few men who will, naturally enough, release them only at an onerous and sometimes distressful rate. The population, rapidly as it is increasing, has not kept up with manufacturing production, and, in certain lines, manufacture is threatened with overproduction; furthermore, economy in purchasing is taking the place of extravagance. Finally, and, in a sense, more important than all, we have a world-wide increase in living expenses, which necessitates increase in salaries, increase in cost of materials, increase in transportation rates, and to such an extent that even in the immediate future success or failure in many a manufacturing operation is going to depend upon the extent to which the manufacturer can eliminate waste and increase the value of his product. Speaking frankly and advisedly and within the knowledge of us all, American manufacture is proceeding to a crisis from the successful issue of which only efficiency will count. Most manufacturers now understand this, some of them dimly and gropingly, but, after all, actually.

The American manufacturer, however, considering him in general terms, and not taking into account the

unmistakable exceptions to the rule, does not know how to proceed in order to gain this efficiency. He is for the most part ignorant of his own factory problems—at any rate, of their full extent. He does not know how to go about it to obtain adequate chemical aid. The fact is that he does not know how to choose a chemist; he does not know the facilities with which this chemist ought to be provided, laboratory and library; he subjects the chemist to the jealousies of foremen and, because he does not give him adequate power, to the stupidity and opposition of workmen; he does not know how to gauge his progress, and hence subjects him to intolerable conditions of suspicion, intrigue, and harassment.

For the reasons mentioned above, I presume that ninety per cent. of so-called research work carried out in factories is many times worse than loss, *worse than loss* because the failure of the individual instance, once and for all time, places *a finale* on the possibility of that particular factory to understand the advantages of applied science.

The facts so stated are valid, and it may be inferred that because of them the American manufacturer is lacking in sense and judgment. This is far from being the case. The American manufacturer may be compared in shrewdness, acumen, and energy with the representative manufacturers of any country on earth. His failure in successful factory practice is not due to

lack of ability, but to the fact that because of his extreme abilities he has managed so far to do without efficiency in his factory practice, so that when thrown suddenly into the necessity of this efficiency he finds himself outside his field of knowledge, and hence peculiarly liable to amateurishness and to the mistakes that follow from it. The men who supported the Keely motor through so many years were not fools, nor were those who invested in the idea of making gold from sea-water; these are merely gross instances of the general amateurishness that pervades all manufacturing practice wherever it comes into contact with natural knowledge and modern science.

First, then, let us say that the American manufacturer is inefficient, and sometimes, it is safe to state, to the extent of fifty per cent. of the value of his product; second, he is confessedly so; today, for the most part, he knows that he is inefficient, although he does not generally know the full extent of his inefficiency; third, being an American, he is quick to learn and quick to act. He desires help. How can he obtain this help?

Considerations such as these some four years ago led me to enter into negotiations with an Eastern corporation for the establishment of some type of cooperative work by which this corporation, with its knowledge of the art and its facilities for large-scale experimentation, might work hand-in-glove with the university, with its large laboratory, library, and con-

sultative facilities, for the solution of some one important problem. The corporation concerned entered heartily into my idea, and we fought it out, back and forth, they representing the corporations of the country and I representing the universities and the public, until finally we had together worried out what appeared to us to be a sane, practical scheme for the betterment of American industry, the industrialists concerned, the university concerned, the advance of useful knowledge, and the public good.

What, then, has become of this grand scheme of research? Is it one, with the nine hundred and ninety-nine other innovations, bound to go down into oblivion? Or is it, on the contrary, of such a character that it is fairly insured permanency as an integral factor in an educational and industrial system?

In order to form an opinion as to this, let us briefly review the history of the various fellowships so far established.

It will be understood that these fellowships were established one after another, each by a different corporation, and each concerned with important problems requiring a chemical solution.

As will be seen in the typical agreement published below, each corporation is insured at least three years' secrecy after the termination of the agreement, and, since this period has in no one instance yet elapsed, it is necessary to refer to the work of each in guarded terms.

PROGRESS IN INDUSTRIAL FELLOWSHIPS

UNIVERSITY OF KANSAS

FELLOWSHIP No. 1, ON THE CHEMISTRY OF LAUNDERING

$500 *a year for two years, with* 10 *per cent. of the net profits*

Mr. F. W. Faragher's fellowship was extended for six months beyond its termination, at double the value, at the end of which time he entered the factories of his donating corporation, where he is doing capable work. On the basis of a part of his researches, the University of Kansas conferred upon him the degree of Ph.D.

FELLOWSHIP No. 2, ON THE STUDY OF DIASTASE

$500 *a year for two years, with* 5 *per cent. of the gross proceeds for three years*

Mr. R. C. Shuey had his fellowship extended by the donating corporation for one year beyond its termination. At the end of this time he had perfected a method for drying alfalfa in such a way as to conserve its diastatic content, as well as its taste, odor, color, etc. If he succeeds in proving the practicability of his process from the standpoint of cost, his work will amply satisfy his donors.

FELLOWSHIP No. 3, ON THE CHEMISTRY OF BREAD

$500 *a year for two years, with an additional consideration*

The donors of Mr. H. A. Kohman's fellowship, the National Association of Master Bakers, in recognition of the value of his other work in behalf of the association, at the termination of his fellowship conferred upon him all proprietary rights in his process of standardizing the large-scale manufacture of salt-rising bread. Mr. Kohman discovered the efficient bacillus for its manufacture, isolated it, grew it in large quantities, and through its use has been able to turn out salt-rising bread of beautifully uniform

quality at the rate of a thousand loaves a day for over a week. He has been offered large considerations for the rights of this process, and on the basis of his general work and at the request of a certain corporation he has been appointed to a new fellowship on bread at the University of Pittsburgh, yielding $2,500 a year (*vide* Pittsburgh Fellowships Nos. 6, 7, and 8). In recognition of Mr. Kohman's work, the University of Kansas conferred upon him the degree of Ph.D.

Fellowship No. 4, on the Utilization of the Constituents of Buttermilk

$500 *a year for two years, with* 10 *per cent. of the net proceeds*

Mr. E. L. Tague, on the termination of his fellowship, succeeded in extracting from buttermilk veritable casein. This casein, in quantities of over a hundred pounds at a time, was forwarded to the paper-makers for actual commercial practice. Their reports afforded a complete vindication of his methods.

Fellowship No. 5, on the Extraction of Utilizable Constituents from Crude Petroleum

$1,000 *a year for two years, with* 10 *per cent. of the profits*

Dr. F. W. Bushong, through two years' labor upon petroleum, has placed the matter of this fellowship upon such a footing that I have recently appointed him to the head of a multiple fellowship yielding him $2,000 a year (*vide* Kansas Fellowships Nos. 13 and 14).

Fellowship No. 6, on Enamel-lined Steel Tanks

$1,300 *a year for two years, with an additional consideration*

On the basis of the work accomplished by Mr. A. J. Weith and Mr. F. P. Brock, the donors of this fellowship

insisted upon taking them over into the corporation six months before its expiration. They have succeeded in constructing an enamel which lies beautifully on steel, which is of extraordinary resistivity, and which affords good promise of being adapted to large-scale application. In addition they have helped to develop a substance which is not glass or enamel at all, and which also lies beautifully on steel, and seems remarkably well adapted in its resistivity, etc., for use as a coating for steel tanks.

This completes the list of fellowships which have expired.

Of the fellowships which are now in operation:

No. 7, ON THE RELATION BETWEEN THE PHYSICAL PROPERTIES OF GLASS AND ITS CHEMICAL CONSTITUENTS

$1,500 *a year for two years, with* 10 *per cent. of the net proceeds*

Dr. E. Ward Tillotson is making splendid progress in this fellowship, both from the standpoint of practical results and along lines of great academic interest. He has won the full regard and confidence of his donors, and it is expected that it will be soon possible to publish some of his more important results that do not have a direct practical application.

His fellowship has been extended through a third year.

No. 8, ON THE CHEMISTRY OF CEMENT AND LIME

$1,500 *a year, together with a large additional consideration*

Dr. J. F. Mackay has carried out through this research a comprehensive investigation into a certain phase of cement manufacture after a fashion such as has never

before been attempted, and which bids fair to be of large importance to cement manufacture.

No. 9, on the Extractive Principles from the Ductless Glands of Whales

$1,000 a year for two years

Mr. E. R. Weidlein was sent up to Newfoundland and Labrador early in June for the purpose of collecting material. He returned in September, completely successful in his quest. He brought back with him over a hundred pounds of suprarenal glands, over a hundred pounds of thyroids, some thymus glands, and a large quantity of other very interesting material. He has already discovered that the extractive principles from the suprarenal glands of whales differ in an interesting fashion from the extractive principles obtained from land animals.

No. 10, on the Chemical Treatment of Wood

$1,500 a year for two years, with a large additional consideration

The first year of this fellowship has just expired. During this short time Dr. L. V. Rednan has succeeded in devising and developing a remarkable and promising process for the improvement of the finish on wood. The finish he obtains, while brilliant and entirely resistive to all ordinary chemical reagents, is forty-three times harder than varnish. He already has patents pending. The material also is useful for application as a resistive coating to steel and to cement, and to brass as a lacquer. It has large uses as well as a binding material in various directions. As the result of this first year's work, the donors of this fellowship requested permission to increase its value, in order to permit the employment of additional aid. It has thus passed from a fellowship yielding a stipend of $1,500 a year to

one yielding a payment of $3,900 per year—and this as the result of one year's work.

No. 11, on Utilities for Borax

$750 a year for one year

This fellowship, unlike the others, was but of one year's duration. On the basis, however, of what Mr. B. C. Frichot has accomplished, I am in receipt of a letter from his donors expressing their cordial appreciation and eagerly requesting a continuance of the fellowship, which, however, was not continued.

No. 12, on the Chemistry of Vegetable Ivory

$1,500 a year for two years, with a maximum cash bonus of $2,000

Mr. J. P. Trickey is taking full advantage of the opportunities for investigation which lie in this subject, and, on the basis of results already achieved, has won from his donors their entire confidence and appreciation.

Nos. 13 and 14, on the Relation of Crude Petroleum to the Manufacture of Soap

$2,750 a year for two years, together with a maximum cash bonus of $5,000

To this fellowship has been appointed the previous holder of Fellowship No. 5, Dr. F. W. Bushong, at a stipend of $2,000 a year, together with an assistant fellow at $750 a year. The work is already progressing in a thoroughly satisfactory way.

No. 15, on the Chemistry of Gilsonite

$750 a year for one year, together with a maximum additional consideration of $2,000

To this fellowship has been appointed Mr. W. E. Vawter. It is just proceeding into operation.

Nos. 16, 17, and 18, on the Chemical Treatment of Wood

$3,900 *a year*

This fellowship takes the place of Fellowship No. 10, and provides for the aid of two additional fellows.

Additional fellowships pending are:

No. 19, on Certain Problems Related to the Utilization of Orange Culls in California

No. 20, on Certain Problems Concerning Oyster Culture on the Western Coast

In recognition of the progress and demonstrated value of this work as a whole, the University of Kansas a year ago constituted it a department by itself. The university has built almost a dozen laboratory rooms for the accommodation of the fellows, and in recognition of the value of their instructional services has, through action by the board of regents, determined that every fellow shall in his instructional work receive the titular professorial distinction which his fellowship stipend warrants.

At the University of Pittsburgh, in which this work is to be carried on as well, I have already received the following important fellowships. These fellowships will go into operation in the coming September (September, 1911).

PROGRESS IN INDUSTRIAL FELLOWSHIPS

No. 1, on the Chemistry of Baking

$750 a year for two years, with an additional cash bonus of $2,000

Nos. 2, 3, and 4, on the Abatement of the Smoke Nuisance

$12,000 a year for two years, together with, collectively, a 49 per cent. interest in the results of the work

This fellowship is intended by the donor rather as a benevolence than for purposes of personal profit. It constitutes, presumably, a fellowship many times larger than any heretofore established for any purpose whatever or in any university.

No. 5, on the Relation of the Pot to the Glass, and for the Elimination of "Strea" in Glass

$1,500 a year for two years, with an additional cash bonus of $2,000

Nos. 6, 7, and 8, on the Chemistry of Baking

Wholly independent of but with the acquiescence of No. 1. For three men, yielding $2,500, $1,500, and $750 a year for two years, together with an additional consideration of not more than $10,000 cash

Fellowships Nos. 1, 6, 7, and 8 were established because of the success of Fellowship No. 3 at the University of Kansas.

No. 9, on Certain Problems Related to the Manufacture of Soap

$1,200 a year for two years

No. 10, on Certain Fundamental Problems Concerning the Nature of Glue

$1,200 *a year for two years*

No. 11, on the Utilization of the Orange Culls of Florida, Particularly the Preservation of Orange Juice

$1,000 *a year for two years, together with an additional maximum cash bonus of not more than* $10,000

Nos. 12, 13, 14, 15, and 16, a Large Multiple Fellowship which is to Deal with the Solution of Certain Problems Connected with Crude Petroleum

$10,000 *a year for two years, with an additional consideration*

The senior fellow has already been appointed at a stipend of $3,500 a year. The other fellows in this particular research will receive stipends ranging from $3,000 down to $1,200.

No. 17, on Improvements in the Manufacture of Composition Flooring

$1,500 *a year for two years, together with an additional consideration of* 1 *per cent. of the sales for a period of five years after the factory installation of the improvement*

No. 18, on Certain Problems Related to the Chemistry of Cement

$1,500 *a year for two years, together with an additional consideration*

Nos. 19 and 20, on the Production of Utilizable Substances from Natural Gas

$4,000 *a year for two years, together with a five per cent. interest in the results*

PROGRESS IN INDUSTRIAL FELLOWSHIPS

These industrial fellowships, both at the University of Kansas and at the University of Pittsburgh, are established through definite agreements between the university and the corporation concerned.

Our present idea of an arrangement which is equitable and advantageous to all concerned may perhaps best be expressed in an agreement given in blank, which I append below:

AGREEMENT FOR INDUSTRIAL FELLOWSHIP NO._____

For the purpose of promoting the increase of useful knowledge, the University of (Pittsburgh or Kansas) accepts from__________________________, having head offices at__________________________, the foundation of an industrial fellowship to be known as____________________ Fellowship.

It is mutually understood and agreed that the conditions governing this Fellowship shall be as follows:

The exclusive purpose of this Fellowship is____ to the furtherance of which the holder thereof shall give his whole time and attention, with the exception of three hours a week, which he shall give to instructional work in the University.

The Fellow shall be appointed by the Chancellor of the University and the Director of Industrial Research; he shall be provided with a separate laboratory and all supplies, reagents, etc., which could be reasonably expected to be in the possession of a large university, for the cost and payment of which his lectures shall be taken in lieu. The donating corporation, on its part, undertakes to co-operate

with the University in this research, in providing him with its sympathy and, on prior consideration, with its factory facilities for large-scale experimentation. The Fellow shall work under the advice and direction of the Director of Industrial Research, and he shall forward periodically through the Director of Industrial Research reports of the progress of his work to ____________________

For the support of this Fellowship, which shall extend through a period of ________ years, ____________________ ____________________ agrees to pay ____________________ ____ per year, payable annually in advance to the University of (Pittsburgh or Kansas), which sum shall be paid by the University in monthly instalments to the holder of the Fellowship.

Any and all discoveries made by the Fellow during the tenure of this Fellowship shall become the property of ____, subject, however, to the payment by it to the Fellow of an additional consideration. This additional consideration to the Fellow shall depend upon the value of the services rendered, and shall not exceed ____ ____ The character of this additional consideration (whether royalties, stock, or what not), its amount, the time or times of its payment, shall be determined by the Board of Arbitration provided for herein. At any time during the tenure of this Fellowship, the holder may, at the option of the donor, take out patents at the expense of the donor, on condition that at the time of making application therefor he assigns all his rights to the donor under the conditions of this Agreement.

At or before the expiration of the Fellowship, the business services of the Fellow may be secured by the donor, for a period of three years, on condition that the terms of such service are satisfactory to the parties at interest.

In the event of any disagreement between the donor and the holder of this Fellowship, it is understood and agreed that such disagreement shall be settled, in so far as the dispute relates to matters of fact, by a Board of Arbitration, consisting of a Representative of the University, a Representative of the Donor, and a Third Person whom these two shall select, that the decisions of this Board shall be binding upon the parties at issue, and that they shall obtain such decision before having recourse to the Courts.

It is also understood and agreed that during the tenure of this Fellowship the holder may publish such results of his investigations as do not in the opinion of the donor injure his interests, and that, on the expiration of the Fellowship, the holder thereof shall have completed a comprehensive monograph on the subject of his research, containing what both he and others have been able to discover. A copy of this monograph shall be forwarded to

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and a copy shall be signed and placed in the archives of the University until the expiration of three years from that date, when the University shall be at liberty to publish it for the use and benefit of the public. In the event that, in the opinion of the company, publication three years after the termination of the Fellowship would unduly injure its interests, the corporation concerned is at liberty to appeal for an extension of time to the Board of Arbitration provided for herein, which, after consideration of this appeal, is at liberty to extend the time of publication to a period which, in its belief, conserves the interests of all concerned.

Dated: Signed on Behalf of the University of (Pittsburgh or Kansas)

____________ ________________

Dated: Signed on Behalf of________________

____________ ________________

The amount of the yearly stipend and the amount of the maximum bonus to be stated in the agreement are both left wholly to the discretion of the donor, with the understanding that the stipend, together with the possible additional consideration, govern the quality of the man that can be obtained for the work. The university pays over the stipend in monthly instalments to the holder of the fellowship.

In addition to the individual fellowships, there has been developed during the last year, as will be seen above, a system of multiple fellowships, requiring for some one problem the intensive work of several men.

What, then, is the meaning of these fellowships? Let me say that their practicality and value depend upon the fact that they truly mirror the spirit of the times, the spirit of the times which is steadily and inevitably doing away with the old age of destructive competition, and is placing in its stead an era of sympathetic co-operation. Men have discovered that they can do together what they cannot do in conflict. These fellowships are an explicitly expressed demonstration of the spirit of the times.

Let us look, then, for a moment, at this mutuality from the standpoint of its constituent factors:

First, for the industrialist. From the standpoint of the industrialist this arrangement is an immense privilege. The extraordinary facilities and powers which result from this arrangement give him results which, it

is safe to say, could not be otherwise obtained, and the responsibility for obtaining these results is shifted from the officials of the company, who are, in most instances, wholly amateurs.

Next, since it is appearing that it is a case of "once a fellow, always a fellow," we do nct lose interest in these young men when they pass over to the corporations, nor do we lose interest in the corporations. They are our friends. The result is that it is becoming apparent that through this arrangement the industrialists may learn the business of applying science to practical ends.

Still again, wholly unexpected and valuable relations have appeared as the number of fellowships has increased. It is simply extraordinary, for example, the way in which these fellows are able to help one another, as they are taught to do to a *discreet* extent, and it seems that as their number increases this power of discreet, mutual helpfulness increases in what might be called "geometrical progression." It must be understood that personal integrity is the *sine qua non* to election into these fellowships, and that, in consequence, it is in a certain sense a fraternity.

Then, again, it has appeared that as the number of fellowships increases a mutual helpfulness of the constituent corporations, one to another, has appeared, with striking results. It should be said that these corporations do not know one another, as they nearly all desire

no publicity in the establishment of a fellowship, but as the business of all of them passes through the office of the director, remarkable opportunities for helpfulness appear, and, of course, are taken advantage of. Furthermore, quite outside the actual direct business of the fellowships, opportunities for general helpfulness to the corporations appear and are taken advantage of.

Finally, with regard to the industrialists of the country, it may be said that what is called in chemistry the "catalytic" influence of these fellowships is already beginning to be felt, and it may be reasonably predicted that as their number increases their influence will leaven the whole loaf of American industry. They are, as a matter of fact, a most efficient ferment.

Now, for the public. The public is assured that the results of every one of these fellowships shall, within a reasonable time, be published, free for every one to read and to improve upon. It is true that patents may be taken out at any time, but this is the right of every human being. It is not generally understood, as it should be, that the results of scientific investigation can go to the people only through the industrialists. We often hear it stated that some man eminent in science has "given" his results to the people. This is, in nearly every instance, nonsense. No man can "give" his results to the people. Take, for example, Roentgen's discovery of the X-rays, upon which, of course, he took out no patents. Did he "give" these X-rays to the

people? Not at all. The X-rays could go into medical practice only by the use of X-ray bulbs, and these X-ray bulbs were manufactured and improved by various corporations, through whose factories they went to the people. These corporations, naturally and not at all improperly, placed on these X-ray bulbs all that the trade would bear. The fact that Roentgen, for example, took no money for his research simply added that much to the corporations concerned; his generosity did not make the slightest difference to what the people paid. But let us understand that industrialists may come and industrialists may go, but that every new, significant fact hangs on forever, as a permanent gift to the human race in its struggle for that unknown goal toward which it is proceeding.

To the young men concerned in these fellowships I need hardly say that it gives them the double opportunity—and no man can want more—both of service and of reward.

What about the relation of these fellowships to the university? Is the establishment of these fellowships properly a university function? About this there can be, indeed, not the slightest question. The objects of every university worthy of the name are three in number: (1) The adequate instruction of the young men and women who frequent its halls; (2) The creation of knowledge, both pure and applied; (3) The dissemination of knowledge, both pure and applied, and the ren-

dering of service through such to its outside environment. This tripartite ideal is not to be questioned, nor is any one factor of the three of more importance than the others. The university which does not devote itself to research, both pure and applied, is a dead limb on the tree of our civilization, for without research it can neither teach nor can it be of service. Researches carried out in accordance with these fellowships result in new knowledge, both pure and applied. In the instance of no one fellowship has there resulted new applied knowledge only. When these fellowship researches are ultimately published it will be found that each and every one of them has increased the sum of human knowledge quite outside of practical ends. The fact that they have increased the sum of knowledge toward practical ends does not, however, render them any the less valuable. New useful knowledge obtained mainly at the expense of a private corporation is just as valuable to the human race as the most useless of academic knowledge obtained through the expenditure of millions on the part of private benevolence.

Through these fellowships, also, the university fulfils its educational function. It can take the best brains and training of the whole country and form them, through notable and useful achievements, into the highly specialized service which modern manufacture and the human needs of modern men require. No one who has met the young men constituting the staff of these in-

dustrial fellowships would doubt for an instant but that they will grow into men of power and influence for good. It must be remembered that they are trained men, that fully half of them have already their degree of doctor of philosophy from the great universities, and that the university in giving them the opportunity of training themselves to these highest and noblest ends is doing the highest university service.

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THE END